AMERICAN CONCRETE INSTITUTE

PROCEEDINGS

OF THE

NINETEENTH ANNUAL CONVENTION

Held at Cincinnati, O.

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BY-LAWS.

AMERICAN CONCRETE INSTITUTE.

ARTICLE I.

MEMBERS.

SECTION 1. Any person engaged in the construction or maintenance of work in which cement is used, or qualified by business relations or practical experience to co-operate in the purposes of the Institute, or engaged in the manufacture or sale of machinery or supplies for cement users, or a man who has attained eminence in the field of engineering, architecture or applied science, is eligible for membership.

SEC. 2. A firm or company shall be treated as a single member.

SEC. 3. Any member contributing annually twenty or more dollars in addition to the regular dues shall be designated and listed as a Contributing Member.

SEC. 4. Application for membership shall be made to the Secretary on a form prescribed by the Board of Direction. The Secretary shall submit monthly or oftener, if necessary, to each member of the Board of Direction for letter ballot a list of all applicants for membership on hand at the time with a statement of the qualifications, and a two-thirds majority of the members of the Board shall be necessary to an election.

Applicants for membership shall be qualified upon notification of election by the Secretary by the payment of the annual dues, and unless these dues are paid within 60 days thereafter the election shall become void. An extract of the By-Laws relating to dues shall accompany the notice of election.

SEC. 5. Resignations from membership must be presented in writing to the Secretary on or before the close of the fiscal year and shall be acceptable provided the dues are paid for that year.

ARTICLE II.

OFFICERS.

SECTION 1. The officers shall be the President, two Vice-Presidents, six Directors (one from each geographical district), the Secretary and the Treasurer, who, with the five latest living Past-Presidents, who continue to be members, shall constitute the Board of Direction.

SEC. 2. The Board of Direction shall, from time to time, divide the territory occupied by the membership into six geographical districts, to be designated by numbers.

SEC. 3. There shall be a Committee of five members on Nomination of Officers, elected by letter ballot of the members of the Institute, which is to be canvassed by the Board of Direction on or before September 1 of each year.

The Committee on Nomination of Officers shall select by letter ballot of its members, candidates for the various offices to become vacant at the next Annual Convention and report the result to the Board of Direction who shall transmit the same to the members of the Institute at least 60 days prior to the Annual Convention. Upon petition signed by at least ten members, additional nominations may be made within 20 days thereafter. The consent of all candidates must be obtained before nomination. The complete list of candidates thus nominated shall be submitted 30 days before the Annual Convention to the members of the Institute for letter ballot, to be canvassed at 12 o'clock noon on the second day of the Convention and the result shall be announced the next day at a business session.

SEC. 4. The terms of office of the President, Secretary and Treasurer shall be one year; of the Vice-President and the Directors, two years. Provided, however, that at the first election after the adoption of this By-Law, a President, one Vice-President, three Directors and a Treasurer shall be elected to serve for one year only, and one Vice-President and three Directors for two years; provided, also, that after the first election a President, one Vice-President, three Directors and a Treasurer shall be elected annually.

The term of each officer shall begin at the close of the Annual Convention at which such officer is elected, and shall continue for the period above named or until a successor is duly elected.

A vacancy in the offie of President shall be filled by the senior Vice-President. A vacancy in the office of Vice-President shall be filled by the senior Director.

Seniority between persons holding similar offices shall be determined by priority of election to the office, and when these dates are the same, by priority of admission to membership; and when the latter dates are identical, the selection shall be made by lot. In case of the disability or neglect in the performance of his duty of any officer of the Institute, the Board of Direction shall have power to declare the office vacant. Vacancies in any office for the unexpired term shall be filled by the Board of Direction, except as provided above.

SEC. 5. The Board of Direction shall have general supervision of the affairs of the Institute and at the first meeting following its election, appoint a Secretary and from its own members a Finance Committee of three; it shall create such special committees as may be deemed desirable for the purpose of preparing recommended practice and standards concerning the proper use of cement for consideration by the Institute, and shall appoint a chairman for each committee. Four or more additional members on each special committee shall be appointed by the President, in consultation with the Chairman.

Sec. 6. It shall be the duty of the Finance Committee to prepare the annual budget and to pass on proposed expenditures before their submission to the Board of Direction. The accounts of the Secretary and Treasurer shall be audited annually.

Sec. 7. The Board of Direction shall appoint a Committee on Resolutions, to be announced by the President on the first regular session of the annual convention.

Sec. 8. There shall be an Executive Committee of the Board of Direction, consisting of the President, the Secretary, the Treasurer and two of its members, appointed by the Board of Direction.

Sec. 9. The Executive Committee shall manage the affairs of the Institute during the interim between the meetings of the Board of Direction.

Sec. 10. The President shall perform the usual duties of the office. He shall preside at the Anual Convention, at the meetings of the Board of Direction and the Executive Committee, and shall be ex-officio member of all committees.

The Vice-Presidents in order of seniority shall discharge the duties of the President in his absence.

Sec. 11. The Secretary shall be the general business agent of the Institute, shall perform such duties and furnish such bond as may be determined by the Board of Direction.

Sec. 12. The Treasurer shall be the custodian of the funds of the Institute, shall disburse the same in the manner prescribed and shall furnish bond in such sum as the Board of Direction may determine.

Sec. 13. The Secretary shall receive such salary as may be fixed by the Board of Direction.

Article III.

meetings.

Section 1. The Institute shall meet annually. The time and place shall be fixed by the Board of Direction and notice of this action shall be mailed to all members at least thirty days previous to the date of Convention.

Sec. 2. The Board of Direction shall meet during the Convention at which it is elected, effect organization and transact such business as may be necessary.

Sec. 3. The Board of Direction shall meet at least twice each year. The time and place to be fixed by the Executive Committee.

Sec. 4. A majority of the members shall constitute a quorum for meetings of the Board of Direction and of the Executive Committee.

ARTICLE IV.

DUES.

SECTION 1. The fiscal year shall commence July 1st.

SEC. 2. The annual dues shall be ten dollars ($10.00) payable annually in advance from first of the month following notification of the applicant of his election by the Board of Direction.

SEC. 3. Each member shall be entitled to receive one copy of one volume of the Proceedings for each membership year and additional volumes at a price fixed by the Board of Direction.

SEC. 4. A member whose dues remain unpaid for a period of three months shall forfeit the privilege of membership and shall be officially notified to this effect by the Secretary, and if these dues are not paid within thirty days thereafter his name shall be stricken from the list of members. Members may be reinstated upon payment of all indebtedness against them upon the books of the Institute.

ARTICLE V.

RECOMMENDED PRACTICE AND SPECIFICATIONS.

SECTION 1. Proposed Recommended Practice and Specifications to be submitted to the Institute must be mailed to the members at least thirty days prior to the Annual Convention, and as there amended and approved, passed to letter ballot, which shall be canvassed within sixty days thereafter, such Recommended Practice and Specifications shall be considered adopted unless at least 10 per cent of the total membership shall vote in the negative.

ARTICLE VI.

AMENDMENT.

SECTION 1. Amendments to these By-Laws, signed by at least fifteen members, must be presented in writing to the Board of Direction ninety days before the Annual Convention and shall be printed in the notice of the Annual Convention. These amendments may be discussed and amended at the Annual Convention and passed to letter ballot by a two-thirds vote of those present. Two-thirds of the votes cast by letter ballot shall be necessary for their adoption.

SUMMARY OF PROCEEDINGS OF THE NINETEENTH ANNUAL CONVENTION.

Sinton Hotel, Cincinnati, Ohio.

FIRST SESSION, MONDAY, JANUARY 22, 1923, 2 P. M.

The convention was called to order by William P. Anderson, President of the American Concrete Institute.

The following papers were read and discussed:

"The Development of Reinforced-Concrete Pipe for Transmission of Water Under Pressure," by W. G. Chace.

"Developments in Surface Treated Concrete," by R. F. Havlik.

The latter paper was accompanied by a demonstration of methods of molding concrete pieces.

The report of Committee P-1, on Standard Building Units, was presented by W. R. Harris, chairman. This report consisted of the presentation of (1) "Proposed Standard Specifications for Concrete Building Block and Concrete Building Tile" and (2) "Proposed Standard Specifications for Concrete Brick."

After discussion the two specifications were accepted as tentative standards.

The following paper was read and discussed:

"Report of Results of Fire Tests of Concrete Building Block," by Leslie H. Allen.

This was accepted as a progress report of Committee P-5, on Fire Resistance of Concrete Building Units.

The meeting was terminated by a discussion of a paper entitled "Design of Reinforced-Concrete Pipe," which had been prepared merely for discussion purposes by C. F. Buente, chairman, Committee P-7, on Pipe, Drain Tile, and Conduit.

SECOND SESSION, MONDAY, JANUARY 22, 1923, 8 P. M.

Past-President W. K. Hatt in the chair.

The following papers were read and discussed:

"Design and Construction Features of the Ideal Section of the Lincoln Highway," by W. G. Thompson.

"The Trend of Design and Construction of Concrete Roads," by H. Eltinge Breed.

"Correction Data for Comparative Test Results from Field Specimens," by G. W. Hutchinson.

The report of Committee J-2, the Joint Committee on Concrete Culvert Pipe, was read by B. S. Pease, chairman.

The report of Committee S-6, on Concrete Roads and Pavements, was read by W. M. Acheson, chairman. This report consisted in the presentation of a tentative standard specifications for one course concrete highways. The specification was accepted as tentative.

Vice-President A. E. Lindau in the chair.

The report of Committee E-3, on Research, was read by W. K. Hatt, chairman. It consisted of a paper entitled "Research in the Field of Concrete."

THIRD SESSION, TUESDAY, JANUARY 23, 1923, 9.30 A. M.

W. R. Harris in the chair.

The following papers were read and discussed:

"Discussion and Demonstration of the Application of Scientific Methods of Making Concrete to the Requirements of Concrete Products Manufacturers," by Duff A. Abrams and Stanton Walker. This was accompanied by a demonstration of actual test methods.

"How to Make More Money in Concrete Building Units Manufacture," by John W. Lowell.

There was a round table discussion of products, plant operating and cost problems.

During the morning, a separate session, with Leslie H. Allen in the chair, was held at which the following papers were read and discussed:

"Estimating and Cost Keeping," by Frank R. Walker.

"Methods of Measurement," by J. W. Ginder.

FOURTH SESSION, TUESDAY, JANUARY 23, 1923, 2 P. M.

President W. P. Anderson in the chair.

The Secretary read the report of the Board of Direction, reviewing Institute affairs of the year.

The meeting voted to send the proposed amendments to the by-laws to letter ballot for adoption.

There followed a round table discussion "For the Good of the Organization."

The following papers were read and discussed:

"A New Design for Concrete Water Tanks," by W. S. Hewett. (Read by F. R. McMillan.)

"Effect of Impure Water on the Strength of Concrete," by Duff A. Abrams.

"Design of Elastic Structures from Paper Models," by George E. Beggs.

TUESDAY, JANUARY 23, 1923, 8.30 P. M.

The Wason Medal was presented to George E. Beggs, Princeton University, for his paper "An Accurate Mechanical Solution of Statically Indeterminate Structures by Use of Paper Models and Special Gages." The medal was presented by Frank C. Wight, chairman of the Wason Medal Committee.

FIFTH SESSION, WEDNESDAY, JANUARY 24, 1923, 9.30 A. M.

Past-President H. C. Turner in the chair.

The report of the Institute representation on the Joint Committee and Reinforced-Concrete was read by S. C. Hollister, chairman of the Institute Representation.

The report of the Committee on Nomenclature was read by W. A. Slater, chairman. This consisted of a series of definitions under the title "Defining the Special Terms Peculiar to Concrete Work."

The following papers were read and discussed:

"Design, Construction and Cost of Concrete Stadiums," by Clyde T. Morris.

"Design and Construction of University of Kansas Stadium," by C. C. Williams.

"Major Factors in the Design and Construction of the University of Pennsylvania Reinforced-Concrete Stadium," by H. T. Campion.

The Secretary announced that the letter ballot had resulted in the election of the following officers for the ensuing year:

President, William P. Anderson.
Vice-President, A. E. Lindau.
Treasurer, Harvey Whipple.
Directors, Third District, S. C. Hollister; *Fourth District*, J. C. Pearson; *Fifth District*, D. A. Abrams.

SIXTH SESSION, WEDNESDAY, JANUARY 24, 1923, 2 P. M.

Past-President Richard L. Humphrey in the chair.

The following paper was read and discussed:

"An Interesting Case of a Dangerous Aggregate," by J. C. Pearson and G. F. Laughlin.

The following resolution was introduced by Mr. Leslie H. Allen and unanimously adopted by the meeting:

It is resolved that it is the sense of this meeting that the rules of measurement adopted by the American Concrete Institute in 1913 be revised and amended, and the Institute requests the Board of Direction to appoint a committee to revise and amend these rules, having particular reference to the relation of cost estimating and cost accounting to the subject, this committee to be instructed to report at the next convention a revised set of rules of measurements with reasons therefor.

The rest of the session was given over to a discussion of the "Question Box" which consisted of twenty questions on subjects of interests to concrete users.

The report of Committee C-2, on Concrete Floor Finish, was presented by N. M. Loney, chairman. It consisted of Tentative Standard Specifications for Concrete Floors. The specification were adopted as tentative.

The report of Committee S-4, on Concrete Storage Tanks, was presented by W. E. Hart, secretary. The report consisted of the presentation of Proposed Standard Specifications for Concrete Fuel Oil Storage Tanks. By vote of the meeting the specifications were accepted as Tentative Recommended Practice and Tentative Specifications for Concrete Fuel Oil Tanks.

The report of Committee S-3, on Reinforced and Plain Concrete Sewers and Conduits, was presented by A. C. Irwin, of the committee. This consisted in the presentation of Tentative Standard Specifications for Monolithic Concrete Sewers and Recommended Rules for Concrete Sewer Design, which were accepted by the meeting.

The report of Committee C-1, on Contractor's Plant, was presented by J. G. Ahlers, chairman. The report was received.

SEVENTH SESSION, WEDNESDAY, JANUARY 24, 1923, 8 P. M.

Vice-President A. E. Lindau in the chair.

The following paper was read and discussed:

"Thoughts on Concrete Houses," by J. C. Pearson.

The report of Committee C-3, on Treatment of Concrete Surfaces, was presented by J. C. Pearson, chairman. It consisted of the presentation of (1) Recommended Practice for the Finish of Exterior Surfaces of Concrete Industrial Buildings. It was voted that these be accepted as tentative standards. (2) "Proposed Revised Standard Recommended Practice for Portland Cement Stucco." It was voted by the meeting that this be sent to letter ballot as standard.

The following papers were read and discussed:

"A New Art of Concrete," by Lorado Taft.

"How 'The Fountain of Time' Was Reproduced in Concrete," by J. J. Earley.

The report of Committee S-5, on Concrete Houses, was read by its chairman, John A. Ferguson. It was accepted as a progress report.

EIGHTH SESSION, THURSDAY, JANUARY 25, 1923, 9.30 A. M.

Vice-President M. M. Upson in the chair.
The following papers were read and discussed:

"Some Defects in Concrete Buildings—Their Causes and How to Minimize by Proper Design," by H. D. Loring.

"Inundation Methods for Measurement of Sand in Making Concrete," by W. A. Slater and G. A. Smith.

This was followed by discussion by R. L. Bertin and a demonstration of the methods outlined in the Slater and Smith paper.

"Effects of Serious Formwork Fire on Large Warehouse Job," by A. R. Lord.

NINTH SESSION, THURSDAY, JANUARY 25, 1923, 2 P. M.

President W. P. Anderson in the chair.
The report of Committee E-7, on Waterproofing, was read by the chairman, S. C. Hollister. It was accepted as a progress report.
Frank C. Wight in the chair.
The following papers were read and discussed:

"Report of Field Tests of Methods Used in New York Building Construction for Obtaining Concrete of Specified Strength," by J. G. Ahlers.

"An Analysis of the Variables in Concrete from the Construction Standpoint with Some Results of Job Tests," by W. P. Bloecher.

Report of Committee E-6, on Destructive Agents and Protective Treatments, read by M. M. Upson, chairman. This consisted of a progress report on destructive agents and protective treatments, dealing particularly with the action of sea water. It was accepted as a progress report.

THE WASON MEDAL.

Awarded Each Year to the Author of the Most Meritorious Paper Presented to the Previous Annual Convention.

Awarded 1922 to

George E. Beggs, for his paper, "An Accurate Mechanical Solution of Statically Indeterminate Structures by Use of Paper Models and Special Gages."

Previous Awards.

1916—A. B. McDaniel, "Influence of Temperature on the Strength of Concrete."

1917—Charles R. Gow, "History and Present Status of the Concrete Pile Industry."

1918—Duff A. Abrams, "Effect of Time of Mixing on the Strength and Wear of Concrete."

1919—W. A. Slater, "Structural Laboratory Investigations in Reinforced Concrete Made by Concrete Ship Section, Emergency Fleet Corporation."

1920—W. A. Hull, "Fire Tests of Concrete Columns."

1921—H. M. Westergaard, "Moments and Stresses in Slabs."

Some Defects in Concrete Buildings—Their Causes and How to Minimize by Proper Design.

By H. D. Loring.*

The place given this paper on the "Good Concrete" program has led to a literal treatment of the subject, although I cannot refrain from pointing out that many errors in the design of concrete buildings are not those that lead to collapse or even to cracks. The loss of labor and material due to wasteful designing or poor judgment in the selection of type of construction, loads, stresses, are real though unseen, losses not less than such defects as are pointed out here.

Structural defects in reinforced-concrete usually show as cracks; occasionally as disintegration without definite cracks, and less commonly as spalling or buckling. Such defects may be the result of accident that cannot reasonably be foreseen but many of them can be prevented by proper design and precautions in construction. We are concerned here more particularly with those that can be corrected in the drafting room, and while most of those pointed out in this paper are not particularly unknown or obscure, it may be profitable to bring them again to the attention of designers.

Many structures are injured or rendered unsightly by cracks due to the applied loads for which they are supposedly designed. Pure blunders we are, of course, not concerned with, but sometimes there are factors easily overlooked. Walls to retain earth or water are frequently designed as vertical cantilevers, and such walls seldom give trouble, when they are straight. When, however, two such walls are built at right angles to each other as a continuous structure, a wide crack is very apt to appear near the corner, because each wall bends, under the earth or water pressure, enough to cause rupture, even when considerable amounts of steel are bent around the corners. The rigidity of continuous floor construction is so well fixed in the minds of most building designers that they may not, at first thought, consider how comparatively limber a cantilever is, but recalling that a cantilever of uniform cross section under uniform load deflects 48 times as much as a similar fixed beam with the same span and load, will give one a measure of the deflection that may be expected in cantilever walls. The simplest and often the best preventative of such cracks is to design the walls as separate structures with a joint near the corners. Where liquids are to be retained this is not practicable and the two walls may be connected by a curved or broken section of considerable radius with liberal horizontal reinforcements extending into each wall far enough to take care of stresses caused by restraint. For low walls a

*Ferro Concrete Construction Co., Cincinnati, Ohio.

generous fillet in the corner with liberal horizontal reinforcement may be sufficient.

On walls subject to fluid pressure the overturning moment varies as the cube of the height, and is 2.37 times as much on an 8 ft. wall as on a 6 ft. one, although earth retaining walls are usually designed for fluid pressure, skepticism of such alarming precision is probably justified in view of the uncertainty as to just how much pressure earth does exert on a wall. However, several years ago when we were advised that a small retaining wall which had been built five or six years, was buckling out of line, we found that the fill behind it had increased from about 6 ft. to about 8 ft. and was being supported by wooden flash boards held by posts behind the walls. Soaking rains had contributed to the overload which had been sufficient to throw the wall considerably out of line. In choosing factors of safety the possibility of overload from excessive surcharges may well be borne in mind.

A frequent source of trouble in concrete buildings having the roof insulated with a fill of cinders is the buckling of the cement topping placed over this fill to receive the roofing. The topping usually is a thin slab of rather lean mortar and unable to withstand the compressive stresses due to expansion at summer temperature, which will frequently raise large blisters. The resulting ridge and cracks are very destructive to roof coverings and are a frequent source of troublesome leaks. Expansion joints are easily made in the topping with some of the prepared strips of bituminous material sold for the purpose or by leaving wood strips which are removed and the space filled with mastic. Such joints should provide for expansion in all directions at the rate of at least ½ in. for every fifty feet.

Cinder fills often become saturated from rains before topping is laid and the water slowly finds the only way out—through the ceiling, resulting in dampness for many weeks or even months. The cost of fill and topping with the cost of carrying their weight to the foundations may amount to 15c or 20c per square foot and at best they do not form as good a foundation for roofing as a solid slab. This leads to the inquiry as to whether they may not be eliminated altogether in many cases. Inasmuch as composition roofing contractors will usually guarantee a dead level roof as readily as a sloping one, filling is not a necessity for forming slopes when it is not desired to pitch the structural slab for this purpose. The best reason for the use of cinder fill is as an insulator to prevent undue condensation on a cold ceiling in winter and excessive heat in the top story in summer. While cinder fills accomplish this result successfully and are desirable in buildings, with thin roof slabs in beam and slab construction, the greater thickness of structural concrete in flat slab construction is in many cases sufficient insulation in itself. We have examined several heated buildings constructed within the last year or two, where the roofing was applied directly to level structural slabs and found them giving satisfaction. In one case, a portion of the building is used for office purposes with a plastered ceiling applied directly to the

concrete and no condensation was noted or other trouble experienced by the occupants. The saving in the cost of roof fill is a considerable item in buildings where low first cost is imperative. In colder climates there is, of course, more necessity for the fill as a heat saver.

While expansion joints in fill toppings are absolutely necessary to prevent trouble in even buildings of moderate size, expansion joints in the building itself are another matter. The question of expansion joints in concrete buildings has been a much discussed one and probably the present tendency is to use them in fewer buildings. We believe they are seldom needed in buildings up to three hundred feet in length. Where they are used, careful designing is necessary to prevent their giving trouble, especially from leaking floors, in buildings where wet operations are carried on.

Perhaps the best form of expansion joint is one in which the adjoining parts are independent cantilevers. Such a joint used in the Anheuser-Busch Building at St. Louis, was described in the technical press a few years ago. In another building, 560 ft. long, it was considered advisable to use an expansion joint which was secured by resting the ends of the beams carrying one side on brackets formed on the girders and columns of the other to form a sliding joint. In this case, however, the frictional resistance developed by the dead load of the construction was sufficient to spall or pull off some of the brackets, rather than permit sliding. In designing such brackets either for expansion joints or to carry future extensions, care should be taken that sliding on the joint will take place before any destructive force may be transmitted to the brackets.

In beams, cracks of the well known shear variety may be caused by forces other than loading; for example, a slight settlement of supports, or of the formwork before the concrete has fully set. These cracks are likely to occur as in shear failures, since the accumulated stresses are greatest at these points. Cracks of this kind can usually be avoided by placing stirrups throughout the beam, not further apart than three-quarters the effective depth, and repairs can be made by cutting out a section of the beam and floor, placing sufficient stirrups and re-concreting.

In many buildings having structural members exposed on the exterior, time and the elements have worked considerable damage spalling and flaking of concrete and exposing steel to corrosion. Frequently the spalling is occasioned by the swelling of steel which has corroded when reached by moisture, due to insufficient covering; perhaps occasionally aided by electrolytic action. The great preventative of such unfortunate results is sufficient concrete protection for the steel. No such members should be designed with less than 2 in. minimum cover and 3 or 4 in. would often be desirable. Where bars are accidentally exposed during construction, the trouble should be remedied at the time. The dense surface finishes produced by rubbing in cement grout, are a protection to the building as well as an addition to its appearance, while the bush hammered effects, and other finishes which expose aggregate should only be used when ample cover is given to the steel. Repairs to buildings so damaged are difficult

and costly, but should not be neglected. The steel should have all loose scale wire-brushed or otherwise removed before pointing is done and every precaution taken to secure a bond for the pointing mortar. Metal lath may sometimes be used to advantage by tying to the reinforcing with galvanized wire. Painting the steel with a bituminous coating before pointing with mortar may prevent further corrosion.

Some building codes encourage the placing of steel too near the surface by specifying that in vertically rodded columns only the concrete inside the ties may be counted to carry load. This appears to be based on an incorrect idea of the use of ties in vertically rodded columns; their function is, of course, only to stay the vertical bars and they cannot add anything to the strength of the concrete in the way that closely spaced spiral hooping does. Such test data as the writer has examined do not show any effect of changing the location of vertical steel in a column, as long as it is symmetrically disposed. In designing columns for bending moment, the position of steel must, of course, be taken into account.

There are many other points for the designer to bear in mind to facilitate the production of good concrete in the field, such as the proper location of construction joints, the reinforcement of re-entrant angles, the avoiding of sharp, thin sections and the design of sections and disposition of reinforcement that will permit concrete to flow into place readily. The skill of the organization doing the work has a bearing on permissible details. The speaker recalls a structure consisting mainly of 4 in. walls, 26 ft. high, which were poured in two lifts and showed hardly a flaw when the forms were removed. These walls had one layer of steel only, in the center, but in some work 8 in. walls would be the thinnest that could be used with confidence of tight work.

The designer who bears in mind that concrete is a brittle, porous material, manufactured in molds and usually used in continuous structures, will be likely to design structures, which with reasonably good field work will not only have the requisite strength but are satisfactory in finish and as durable as we have a right to expect from the widely advertised "Concrete for Permanence."

DISCUSSION.

Mr. Ferguson.

JOHN A. FERGUSON.—Mr. Loring has made the statement that it is a mistake to compute the load carrying capacity of columns by basing the calculations upon the area of the concrete within the planes of the reinforcing. If anyone will calculate the added unit stress as applied to the inner area in order to apply the load to it that would be calculated for the total area of the column as Mr. Loring advocates, it will be found to be not so very great.

The writers of building codes have to prepare the requirements in such a manner that all contingencies will be taken into account. It is usual with hooped columns for the concrete outside of the hooping to fall off during a fire. There are several reasons why this takes place. It is necessary to consider such facts in preparing design specifications if the work is going to be any better than a guessing contest.

I have witnessed and studied the results of many fire tests and of columns subjected to a real fire, invariably the whole column is weakened by fire, even though the eye cannot distinguish that the concrete has been injured in any way. The foregoing is based upon test data of columns tested before and after being subjected to fire, in parallel tests. In some materials the loss has been as high as forty percent, while in other materials the loss does not exceed ten percent. Limestone aggregate loses the least of all the aggregates known, and silicious gravel loses the most strength of all.

It is then quite plain that the practice of deducting the area outside the vertical reinforcement and of the hooping is not so indefensible as it would seem if one has not studied the problem from all sides.

It is then quite plain that the practice of deducting the area outside the vertical reinforcement and of the hooping is not so indefensible as it would seem if one has not studied the problem from all sides.

Mr. Anderson.

W. P. ANDERSON.—I think that the point that it is necessary to have some protection is perfectly true, but the amount of that protection should not be based on the distance of the steel from the face; it should be based on the character of the aggregate, the likelihood of fire and things of that kind. The distance of the steel from the face of the column hasn't got anything to do with the amount of protection you need.

Mr. Ferguson.

MR. FERGUSON.—I agree with the remarks of Mr. Anderson, but wish to make one more point in connection with this discussion. It is very usual to note that after the fire the vertical rods in these columns have been elongated and that they have buckled and forced the concrete out from the rest of the column. Therefore, in my work, I do not allow as high a load as might be considered safe if one had not taken into consideration all the conditions in the case. Of course, in assuming for safety's sake that the steel in a column is not accurately placed and is so often too near the surface of the column, and directly in the corner

(the very worst place) of a rectangular column, one has not considered the proposition of Mr. Loring to place the steel further within the column. Mr. Ferguson.

President Anderson.—That is a point Mr. Loring wanted to bring out. We want to leave the steel 3 in. back. An 1½ in. fireproofing may be specified; then the tendency of the contractor is to put his steel 1½ in. from the outside, while the effect of leaving it 1½ in., if the concrete is pervious, would be to have it spall off and do injury. Mr. Anderson.

Mr. Ferguson.—In designing concrete and reinforced-concrete structures, one has so many factors that are not encountered in designing structures to be built of other materials. I would like to suggest that there might be a weakness in hooped columns not entirely suspected if the practice of considering the area outside of the hooping is to prevail, even if the reinforcing is to be placed three inches back from the face of the concrete. This weakness will be observed in every single column so reinforced and subjected to fire. The outer layer of concrete expands in two directions, it is then more easily torn from the core because of the smaller net area of concrete between the hoops, and since this outer layer is expanding, circumferentially, the concrete between the hoops is in tension. Mr. Ferguson.

I believe that it is necessary to protect the layer in which the hooping steel lies, and that this protection should be as suggested by Mr. Loring. I however wish to sound a timely warning to those who take the thoughts advanced and apply them in such a manner that harm is done. Therefore based upon experience, I would not fear columns rectangular in section calculated upon the whole area of the section, provided that the vertical rods have been embedded even more than three inches, the further in they are the better. Three inches is the very least embedment that should be considered in this case. However in the case of the column reinforced with vertical rods and roops or helical layer of steel, it becomes necessary to take into consideration only the concrete within the hooping in view of the facts of which I have spoken before.

President Anderson.—I think it should not be done that way. I do not see why you do not just leave a certain distance on the outside of the column; don't make that distance depend on placing the steel, providing the steel is placed inside of that distance. Mr. Anderson.

A. V. Bekay.—In New York City the building department allows the entire area of the concrete covering to be figured to carry the load, and on a 1: 2: 4 mix they allow 500 lb. per sq. in. on the actual section of the concrete, and 6000 lb. per sq. in. on the net area of the steel. In case of fire this 500 lb. allowance is really based on the actual strength of the column at a 28-day test, and if a fire really does break out in a building, in most cases it happens when the building is occupied. At that time the concrete is usually over three to four months old, and with that point in view it would be fair to figure the actual area of the column carrying that amount of load and figuring that the additional strength of the column at that age would make up for the difference in the fire hazard. In other words, instead of figuring 500 lb. per sq. in. on the Mr. Bekay.

Mr. Bekay. reduced area of the column, you could figure 500 lb. per sq. in. on the entire area of the column, and if the fire reduces the actual section of the column say about 1½ in. penetration on all sides, the reduced area would safely carry the load at a time when the column is older and more able to carry fire stresses.

Mr. Ahlers. J. G. AHLERS.—Last year we talked about this same thing, fire protection around columns. If we would only bear in mind how few fires we have in concrete buildings where this protection goes into effect, and think of the tremendous penalty that would be put on concrete work, the minute a lot of fire protection is placed on all columns where it never will be used, we would not attach so much importance to this. As far as I know there are very few fires where concrete buildings have been totally destroyed and where it has not been perfectly possible after a fire to repair the columns and put them in working use again. To impose a penalty on the concrete industry by doing in all buildings beforehand, something that can be repaired after a fire, does not seem to me at all fair. I think Mr. Loring's recommendation is very good and believe we ought to be allowed to use the full section of the concrete, because, even though damaged, such a column will stand up after a fire and can be enlarged or repaired again.

Mr. Spiker. W. C. SPIKER.—I would like just a word on this subject. It seems to me that what this organization ought to do, as far as it can, is to co-operate with the National Board of Fire Underwriters. We must follow pretty much what they require, and we ought to have a certain amount of protection, and to my mind it ought to be as small as possible. As one of the speakers has said, it is cheaper to repair a building that has been damaged than it is to construct all buildings so that they cannot be damaged. One point was made on two kinds of aggregate; the National Board of Fire Underwriters have a note in their book saying that they prefer limestones. I have talked with some of the officers, and they are considering whether they will not penalize a building that is built out of silica gravel. I think it is a very good point, for buildings which are built out of gravel certainly do not withstand fire as well as those built with limestone. I was called in on a building that was very seriously damaged by fire, and the whole damage was practically due to expansion. It is certain the expansion would not have been so great if the building had been built of limestone.

Notes on a Severe Formwork Fire.

By Arthur R. Lord.*

Within the memory of the youngest of us the construction of concrete buildings halted at the approach of winter. October or November rang down the curtain and left the stage empty until the following April, with all the attendant evils of skilled men out of work and feverish haste in a short working season. Theoretically winter work, if it be admitted that with proper precautions concreting may be safely carried on in winter, must cost more than summer work. Actually the cost is very little greater. While it is inescapable that heating and enclosing the work costs extra money and also that cold weather makes working conditions more difficult, on the other hand concrete materials are cheaper in winter and workmen are eager to hold their jobs as compared with warm-weather inefficiency. As the years have passed concrete operations of greater and greater magnitude have been continued into the winter or even started in winter. One important trouble with concrete work of great dimensions, that of contraction cracks, is undoubtedly minimized by cold weather work. The fire described in this paper constitutes one of the most thorough tests of winter concreting which has come under the writer's notice.

Winter concreting operations are still regarded as hazardous by many prominent engineers. Specifications quite commonly require all work to cease when the temperature falls to 20° F. or 15° F. above zero. The work on the McDougall Terminal was carried forward regardless of temperature, with precautions deemed suitable to the conditions at any particular time. The only real occasion for postponing work, in the opinion of Jacobson Bros., Contractors for this Terminal, is a good snow storm which makes the job "blind." Necessity breeds enterprise in such matters, for Duluth would have an unduly short building season with all the weather below 15° F. left out. Accordingly the construction of this building went on with temperature at time of depositing concrete all the way from 20° above to 20° below zero. A very high rate of progress was also maintained. In one part of the building four floor levels were placed within two and a half weeks, the last being placed on the morning of the fire. In general no loss in time was involved in this building as compared with summer work. In a building constructed under these severe conditions and where the greatest precautions as to removal of forms would be in order, comes a fire which substantially consumed 200,000 sq. ft. of formwork! The only concrete to fall was that poured the same day.

The McDougall Terminal is a large reinforced-concrete and steel

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*President, Tait & Lord, Civil Engineers, Chicago, Ill.

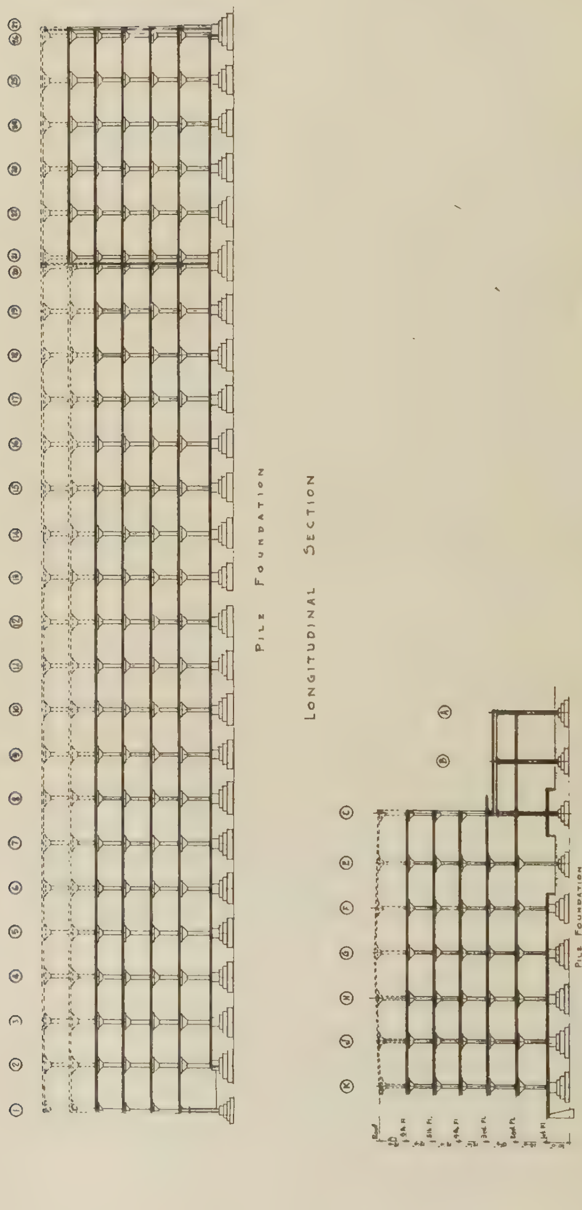

FIG. 1.—DIAGRAMMATIC CROSS AND LONGITUDINAL SECTIONS OF MCDOUGALL TERMINAL WAREHOUSE, DULUTH.

structure with brick curtain walls, now under construction on the lake front at Duluth, and is designed to facilitate the shipping of perishable and other commodities to the east via the all-water route. It is an undertaking in which a great number of Duluth citizens are financially interested and one of the striking facts about the fire was the evident public sympathy and the absence of any adverse criticism.

The terminal is a six story structure, 128 ft. wide above the third floor and 172 ft. wide below, extending some 490 ft. into the lake at present with provisions for future extension. Fig. 1 shows a longitudinal

FIG. 2.—SNAP SHOT OF THE FIRE AT ABOUT 5.45 P. M. AFTER IT HAD BEEN BURNING THIRTY MINUTES.

and a cross section of the structure. Work was being pushed as rapidly as possible. The structural steel work spanning the wagon docks and the railroad tracks in the first story was completed but not fireproofed. The reinforced-concrete flat slab floors and roof would have been completed by Jan. 15. At the time of the fire all of the fifth floor was poured and some 108 ft. of the sixth floor at the south (Lake Superior) end. Formwork and reinforcing steel was in place for another large section of the sixth floor and formwork for 108 ft. of roof.

Some 400 workmen are employed. On Thursday, Jan. 4, 1923, they quit work as usual at five o'clock. At about 5.15 p. m. one of the night watchmen approaching the building saw a small flare in the fourth story

and ran to the office. The Superintendent, Victor Jacobson, and a foreman, hurriedly left the office and proceeded to the fourth floor to extinguish the blaze. When they reached the floor the blaze was still confined to a single small area some 150 ft. from the ladder. However, before they could reach it, the blaze suddenly spread with incredible rapidity and the two men were overtaken by and had to pass through the fire to reach the ladder and safety. When they reached the ground and turned in an alarm at 5.20 the entire fourth story was a sheet of flame. Fig. 2, a *snapshot,* shows the fire at about 5.45 p. m.

The fourth and fifth stories of the building were enclosed in canvas and heated by salamanders. These salamanders had been charged with

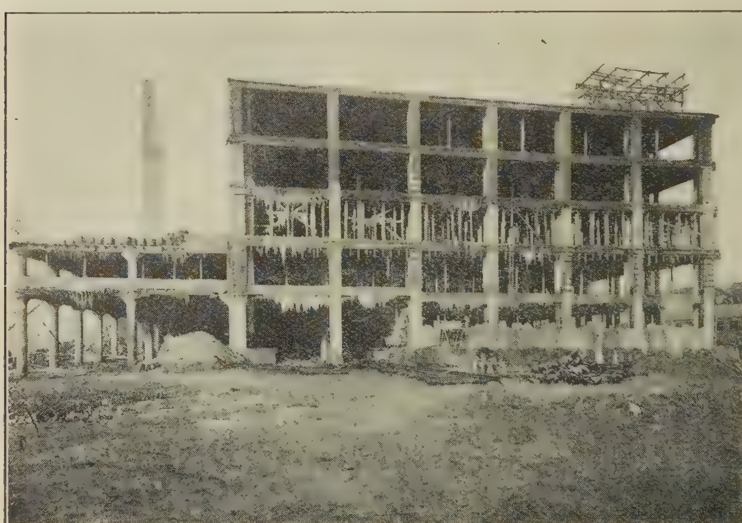

FIG. 3.—VIEW OF SOUTH END ON DAY FOLLOWING FIRE.
Note portion of roof forms left standing by some freak.

anthracite coal for the night just a short time previous to the discovery of the fire. An explanation offered for the rapid spread of the fire is that the upper part of the fourth story was heavily charged with gas from the salamanders and spread the flame throughout the length of the buildings.

The fire apparatus responded promptly but was delayed by the removal of railway cars from the tracks in and beside the building and the hose lines were very long. The formwork in the sixth, fifth and fourth stories burned practically without check and was substantially consumed. Fig. 3 shows a view of the entire building after the fire. Fig. 4 is a view which is typical of the portions of the building where formwork was consumed almost entirely. In the foreground two column capital forms

of metal were still in place and offered some protection but in general the column and drop forms had been removed and the surface of these members received the full heat of the fire. Fig. 5 shows a relatively badly spalled spot in the ceiling in this area. The shores shown in this picture were placed after the fire. Fig. 6 is another general view and shows the relatively greater damage suffered by the columns and drops exposed throughout the fire as compared with the damage to the slab protected for a while by the inch decking. The view shows clearly the joints between boards. Even the locations of joists under the decking

FIG. 4.—TYPICAL VIEW WHERE FORMS WERE BURNED OUT.
Shows fire spalling of columns, beam, wall and slab.

may be seen from the marking of the ceiling. Fig. 7 is a detail view showing this "grid" marking even more strikingly. Fig. 8 is a view in the third story where the formwork was partially consumed. Many of the posts fell, some of the joists either fell or were supported precariously on one or two charred posts. This formwork offered little by way of support to the slab.

Some of the formwork, by reason of "freaks" in the fire or the wind, came through in unexpectedly good shape. A strip of roof forms along the east edge at the south end and about 15 ft. wide was almost intact although the balance of this formwork was completely consumed and little if any water reached it. Some runways two stories high for pouring the

roof also escaped with minor damage. The 140 ft. high tower was protected successfully by the fire department and the mixing and distributing plant is intact except for carts and runways in the fire area. The wind

FIG. 5.—A PARTICULARLY DEEP SPALLING IN THE 4TH FLOOR SLAB.
The shores have been placed since the fire.

was from the north, or slightly east of north, and not strong, during the fire. It carried the flames lengthwise of the building.

The fire, starting in the fourth story and involving that entire story

within a few minutes, spread rapidly to the fifth and sixth stories above. Formwork was in place for the sixth floor at the north end and the reinforcing steel was practically ready for the concrete. All this formwork was completely consumed and the steel dropped and tangled. The steel also underwent an annealing process losing much of the stiffness of hard grade material, so it could be bent as easily as structural grade. The

FIG. 6.—TYPICAL VIEW IN FOURTH STORY, SHOWING HEAT-FRACTURED COARSE AGGREGATE IN COLUMNS AND DROPS.

spirals and column verticals were largely protected by the metal forms but the light wire spirals of this story were so badly twisted and deformed as to be almost useless. At the south end the sixth floor had been placed five days before and its supports were entirely consumed as was the formwork for the roof except for the "freak" noted above. The slab came through this severe test with little more than surface damage.

The fire also dropped from the fourth to the first story but in the first and second stories and to a less extent in the third story it was checked by the fire department and only partly consumed. Most of the

formwork in the first and second stories had been removed and used above. In the northwest corner, however, it was in place in all stories. Here some structural steel was in place and not yet fireproofed and it was

FIG. 7.—A CLOSER VIEW OF A CEILING SHOWING TYPICAL "GRID" MARKING OVER FORMWORK JOISTS AND JOINTS.

most fortunate that it had water in time to save it. The very small damage to the surface of the surrounding concrete shows that the fire made little heat here although it burned for some time. What happens to unprotected structural steel in even a short fire is shown in Fig. 9

which shows all that remains of structural steel trusses and roof framing of a hangar. This fire occurred the same week in Chicago and after twenty minutes collapse occurred, even though the truss members were

FIG. 8.—WHERE THE FIRE ONLY PARTIALLY CONSUMED THE FORMWORK.
Note relatively slight spalling of column and drop.

composed of good sized angles. Workmen engaged in repairing airplanes were content to escape without either tools or street clothes.

The principal damage to the McDougall Terminal was due to the presence in the aggregate of large quantities of granite pebbles which

"pop" when subjected to sudden intense change in temperature. Everywhere that spalling occurred the surface presents heat-fractured pebbles. Where the formwork was entirely consumed the surface of columns and drops, which were exposed for the entire length of the fire, is composed largely of such fractured pebbles. The quartz present in these pebbles was so finely divided as to be scarcely recognizable and the presence of iron further disguised the material. It is doubtful if the average engineer would have classified much of this material as granite although certain pebbles are readily identified. Where the formwork was in place the fire

FIG. 9.—RESULT OF A FIRE IN AN UNPROTECTED STRUCTURAL STEEL BUILDING. Collapse occurred in twenty minutes.

ate its way to the concrete at the cracks between boards or directly over the joists where the extra material made a hotter fire and in such places incipient spalling, commonly very shallow, is general as shown in Fig. 6 and 7. In a fire of this limited duration the square columns stood up as well as the round; in both shapes the damage was a surface damage almost entirely. This showing may have been due also to the fact that the square columns were at the exterior walls of the building where the fire was undoubtedly somewhat less intense. The deepest spalling uncovered some of the slab reinforcing steel, principally in the direct bands which were from one-half to one inch above the forms. The amount of spalling indicates that temperatures considerably in excess of 1070° F. (at which quartz pops) existed over large areas in this fire.

As mentioned previously some panels poured the same day fell when the forms were removed and some actually stood up! Out of sixteen panels placed that morning twelve fell. Fig. 10 is a view of this section. All the columns remained standing except two and all the interior columns save one came through without apparent injury. The exterior columns were inclined slightly inward and have been removed and replaced. The flat slab of the fourth floor directly below came through without injury while two rather deep spandrel beams broke under the impact and have

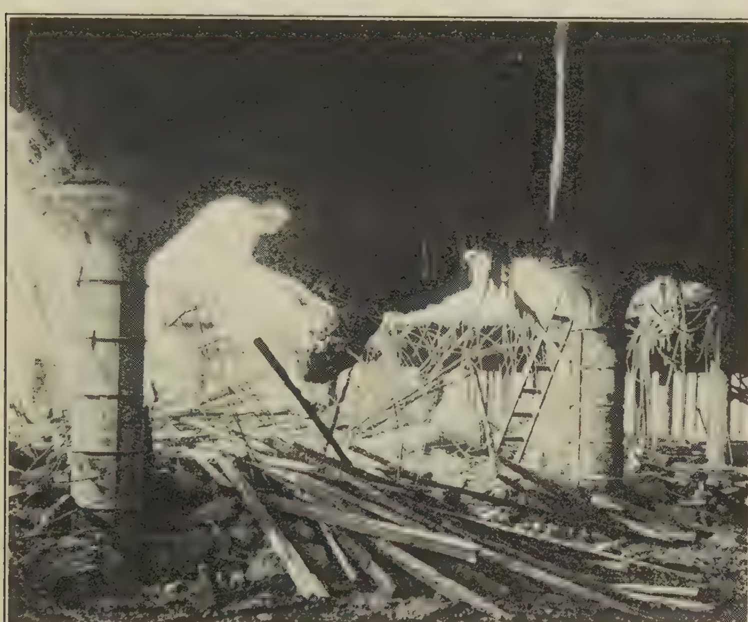

FIG. 10.—TWELVE PANELS OUT OF SIXTEEN POURED THE SAME DAY COLLAPSED. A five day old floor below took the impact.

been torn out and replaced. This floor was five days old. Some fourth story columns on the west face were cracked by the early removal of the slab forms by the fire and will be replaced with new ones. Careful examination failed to show any cracks in the slabs in any part of the building outside the small area that was poured that day.

In view of the excellent behavior of this concrete structure under fire test it may be of interest to describe briefly the manner in which concreting was carried on at this job with a temperature ranging to 20° below zero Fahrenheit. The precautions were less, rather than more than is commonly required. Most specifications require the story above the slab just placed as well as the story below to be enclosed, but in this

case the story above had no canvas protection or salamanders. The materials, both sand and gravel, were heated by means of steam jets in the piles and also in the bins over the mixer, keeping them free from snow and ice and raising them to a temperature of 70° to 80° F. finally as they entered the mixer. The water was also steamed, its temperature being about 70° finally. Concrete was spouted to a hopper and carted to its final position in the forms. It was quite wet. The story below was enclosed in canvas and the salamanders fired a couple of hours before concreting began. The top surface of the freshly deposited concrete was not protected and presumably froze, but as soon as men could walk on it a layer of sawdust and shavings some four inches thick was spread over it. In a half hour or less the slab was warmed through again and the top became decidedly warm to the hand. The floor finish was not placed with the slab but will be placed after the building is fully enclosed and heated. While this method departs from usual practice in several respects the "acid test" of fire seems to have demonstrated its effectiveness under extreme conditions. Workmen removing the concrete which fell and that had been heated only for a part of one day, found it very hard to break with bull-points and sledges.

The fire teaches us some lessons that may be valuable in our education as engineers. In Duluth all available aggregates for concrete work contain large amounts of stone which spall or pop under sudden heat or when suddenly cooled as by a stream of water in a fire. Other cities frequently present a choice and this choice is frequently ignored. A slightly greater price for non-spalling aggregate would seem to be good insurance. This has long been recognized as a result of extensive laboratory tests and experience in other fires—but we forget.

This fire shows also that concreting can be successfully carried on in extremely low temperature without loss of speed or undue increase in cost. At least 200,000 sq. ft. of this structure received a searching fire test which would surely have brought down any frozen concrete in its path.

Even with concrete made from decidedly fire-spalling aggregate the loss of value and time in a severe fire is exceedingly small as compared with that which results from a similar fire in an non-fireproofed steel framed building. The total delay in this construction will hardly exceed two weeks. It should not be overlooked, however, that winter concreting as now carried on does involve a largely increased fire risk which must be fully covered by insurance.

The superintendence and inspection work on this terminal was carried out under the direction of the Architect, Mr. S. Scott Joy, of Chicago. The structural design was made by the writer's firm in accordance with the Duluth and Chicago building codes.

DISCUSSION.

A Member.—What fuel did they have in the salamanders? **A Member.**

A. R. Lord.—They used anthracite coal. They had been using coke, but shortly before the fire occurred they were unable to get coke. The salamanders had been filled about five o'clock, and about 5.15 the fire was discovered. One theory of the rapid spread of the fire is that gas was distilled by this anthracite coal and filled the upper part of the story and when the fire spread it spread with very great rapidity due to that gas. **Mr. Lord.**

J. A. Turner.—I would like to ask about the fireproofing of the steel girders. **Mr. Turner.**

Mr. Lord.—The fireproofing of the structural steel girders was to have been hollow tile, but it had not been placed at the time of the fire. **Mr. Lord.**

M. M. Loney.—What method of repair is going to be used? **Mr. Loney.**

Mr. Lord.—Our plan is as follows: The structural damage is relatively small; very little of the damage went beyond the fireproofing surface. Where the reinforcing has been exposed, we propose to take the cement gun and restore the concrete so that every bit of steel on the job will be enclosed in gunite; there will be no steel showing anywhere, it will be protected by perhaps quarter to half an inch of gunite. We will also restore any damage to the drops with the gun. We will then plaster the fifth and sixth stories with a gypsum plaster which we believe to be the best fire protection we can put on there. **Mr. Lord.**

Mr. Loney.—Where the rods are elongated from the fire, were those rods elongated beyond their original length? **Mr. Loney.**

Mr. Lord.—There was no visible sagging at all; I think the rods are in good shape. The yield point strength of the steel has been reduced to a certain extent, but the areas are so small and infrequent where the fire reached that depth that I do not believe it will seriously affect the strength of the building. **Mr. Lord.**

J. A. Ferguson.—May I ask Mr. Lord if he observed anywhere in the fire a case where the fire protection of the spiral steel columns had expanded away from the rods, so as to become separated from it? **Mr. Ferguson**

Mr. Lord.—None of the spirals were exposed. That is, the 2-in. shell was not entirely taken off at any place that I observed, but I think it is a general feature of all fires—and I have examined a great many and helped to rebuild two or three concrete plants where fires had occurred—that as a general thing the fireproofing shell is somewhat detached from the inner core of the column. I think it is a shrinkage effect largely. I know that in this building and others where fires have occurred, you can take a pick and get off slabs of fireproofing down to the reinforcing steel. The surface was damaged but you had to take a pick to get down to the spiral. **Mr. Lord.**

P. J. Freeman.—I am wondering what might be the effect of this heat on the concrete that was perhaps four days old or younger. I ran into a case of a large reinforced-concrete power building that had been up **Mr. Freeman**

Mr. Freeman. for about a year, made of a rather rich mix, and the concrete was supposed to be first class. They started to put in some guard rails between the columns, and found that when they commenced to drill in, there was a shell of friable concrete on the outside. An investigation was made and after getting together the folks that had done the work, we found they had poured the columns in freezing weather. The job had been walled off with tar paper very carefully, and to insure against freezing, they had put four salamanders around every column. After that we commenced to dig and found that below the steel the concrete was perfect. A star drill would not penetrate it. In ten minutes we could not get in half an inch with good, hard drilling, but there was a soft shell on the outside down to the steel, which had been brought about by this drying action; they had only ⅞-in. forms on the columns and the whole building was carefully walled in with tar paper and canvas. We found that the columns were dried much more at the bottom than up towards the top, because they had the radiated heat from the salamanders. Repairs were possible after they had cleaned off down to the steel and they used a cement gun to do the job.

I am wondering if some of this concrete that had not gotten pretty well set might not show similar conditions after two or three months.

Mr. Lord. MR. LORD.—The entire building that was affected by the fire described in the paper had to be cleaned up; they had 350 men for ten days who went after it with a pickaxe and bull points and sledges and removed every bit of concrete that could come off with any ease at all and took off everything that showed any fire effect, and we found no evidence of any soft concrete. The workmen in some cases went deeper than there was any need for and in some cases went very deep, but we found no such conditions as you suggest.

Mr. Freeman. MR. FREEMAN.—Ours was sound underneath, it was only the dried out shell.

Mr. Lord. MR. LORD.—Where there is spalling in a certain area there is a pebble of granite at the base, and the very nature of the disintegration is such that it takes off everything affected when it explodes.

Mr. Woolson. I. H. WOOLSON.—I am very much interested in the statement that the contractors propose to use gypsum plaster on the concrete. We have heard a good deal of argument in the past to the effect that gypsum and concrete do not unite well together under such circumstances. I am wondering if they have had assurance that a good job can be depended upon.

Mr. Lord. MR. LORD.—Our experience has been that the only plaster that will stick to concrete satisfactorily is the gypsum plaster with gypsum binder; that is the only satisfactory thing we have found in fifteen or twenty years' experience.

Mr. Abrams. D. A. ABRAMS.—We recently carried out some tests in which we are studying the effect of gypsum molds on the strength of concrete. In some the gypsum molds were removed; in some they were not. In cases where we attempted to remove the gypsum, we found a very strong bond between the concrete and the gypsum.

A New Method of Constructing Reinforced-Concrete Water Tanks.

By W. S. Hewett.*

If we review the history of reinforced-concrete in this country for the past thirty years we cannot fail to note the slow progress made in tank construction as compared to the great progress made in the construction of bridges, buildings and similar structures not subject to hydraulic pressure.

From this fact we must conclude either that concrete is not a suitable material for use in tanks or similar structures or that these structures differ so widely from the ordinary structures not subject to water pressure that methods found entirely satisfactory in the latter are unsatisfactory and inefficient in the former.

It is my opinion that concrete is the best material known to engineers for use in the construction of hydraulic structures and that the unsatisfactory results obtained in the past in the construction of tanks are chargeable to the application of ordinary methods to structures which from their nature demand special treatment.

That the ordinary methods of building reinforced-concrete are not satisfactory when applied to tank structures has been, I believe, the opinion of many designing engineers for years. This opinion has been confirmed by experience in the past twenty years. I quote from an editorial in *Engineering News*, April 29, 1915, p. 834:

"The experience with the Attleboro Standpipe has duplicated, possibly in a more pronounced fashion, the experience with practically every reinforced-concrete standpipe in this country over 75 ft. in height. This means that for water pressures exceeding 30 lb. per square inch, *under the methods of design and construction which have hitherto prevailed*, it is nearly impossible to procure a water tight concrete in large monolithic structures."

The great difference between the circular structure subject to hydraulic pressure and an ordinary structure such as a bridge is that the former is in tension in all parts of the side walls while tension in the latter is only local.

Experience has taught us that concrete in compression is very dependable, even inferior concrete may be subjected to high unit stresses in compression without fear of failure. To put concrete in even low tension is to invite trouble. Minute cracks invisible to the naked eye or even fine hair cracks are not likely to be serious in ordinary structures, but such cracks in structures subject to water pressure are likely to cause serious trouble.

*Consulting Engineer, Minneapolis, Minn.

Shrinkage of concrete is a much more important factor in a structure subject to hydraulic pressure than it is in the ordinary structure. This great factor has received but little consideration in existing tanks. In cases where these tanks have been kept wet until filled and then have been kept filled, or partially filled, no serious results have followed from shrinkage. But if we examine the history of tanks that have stood for some time before being filled or have been repeatedly emptied and filled the result of shrinkage is apparent.

Our early tanks of reinforced-concrete were designed without consideration of either shrinkage or tension in the concrete. The horizontal hoops of steel were designed to resist hydraulic pressure. The unit stress per square inch ranged from 10,000 lb. to 13,500 lb. per square inch. The thickness of the walls was evidently determined by the experience of the designer. This method of design prevailed until about 1912. Some of the tanks designed during that period were:

Location	Diameter Ft.	Height Ft.	Year
Attleboro, Mass.	50	102	1904
Waltham, Mass.	100	37	1906
Manchester, Mass.	50	72	1909
Westerly, R. I.	40	70	1910
Lexington, Mass.	30	104.5	1912

The history of the behavior of these tanks is well known to engineers who have taken an interest in the subject. Briefly stated it is as follows:

No absolute failure is recorded.

Troubles encountered were cracking and spalling off of the concrete in the side walls, seepage of water through the side walls, resulting in discoloration of the exterior. Much time and money spent in attempts to find a method of water-proofing that would permit the expansion in the side walls and keep them water tight.

In each of the tanks referred to the bottom of the tank was a flat slab, resting on the ground, with the side walls anchored securely to this slab. This anchorage prevented the expansion of the side walls at the bottom. The expansion of the side walls above this restraint was excessive. Where the work was not continuous these forces attacked the weak horizontal planes due to construction joints.

The history of these tanks is much alike and a statement of the behavior of one may be accepted as applying to all. I quote some of the engineers responsible for the design of these tanks.

The tank at Waltham, Mass., was designed by B. Brewer, City Engineer of Waltham, and J. R. Worcester. The horizontal reinforcing was designed to take the pressure at a unit stress of 12,000 lb. per square inch. Concrete was 1 : 2 : 4. Side walls 18 in. thick at bottom, 12 in. thick at top. The percentage of steel at the base of side walls was approximately 4.23. In March, 1915, Mr. Brewer described the behavior

of this tank before the New England Water Works Association (*Journal* N. E. W. W. A., 1915, p. 189). I quote Mr. Brewer:

"The result has been this. The first year or two there was very little seepage; some at joints, and a good deal of efflorescence, and some stalactite formation on the outside of the wall. After being in use for a year or two the seepage began to increase considerably, so that when the tank was full a considerable portion of it has been and is quite wet."

In the *Journal* of the N. E. W. W. A., of the same date, we find the following regarding the action of the tank at Manchester, Mass., I quote Raymond C. Allen, City Engineer of Manchester.

"I have noticed, first, that the greatest amount of seepage and of leaks has occurred on the south and west sides, where the expansion seems to be the most unequal. I have also noticed that as from time to time the standpipe is lowered entirely and filled again, the successive fillings have produced new points of seepage. At all events, they act a little differently, and are cumulative in their effect. Thus, each time a standpipe is emptied and filled, I believe that a slight increase in seepage for a time at least takes place."

In this same *Journal* appears information regarding experience with several other tanks and all of this experience is along the same line.

The difficulties with the Attleboro, Mass., tank are fully described in *Engineering News*, April 29, 1915.

In none of the above do we find any reference to the effect of shrinkage in the concrete. Because in most cases the greatest amount of seepage occurred on the south exposure of the tank it was inferred that the seepage was due to temperature cracks. But if these cracks were opened by the sun then the greatest seepage would occur when the sun was bright. It is in line with my own observation and experience that the cracks are more numerous on the south side of the tank but I have also observed that seepage is much greater on a dull day or during the night than under the direct rays of the sun. When the water is drawn out of the tank the south side dries out much faster than the north side, with resultant greater shrinkage. If the tank is allowed to remain filled for some time a part of this seepage stops, regardless of the action of the sun.

The side walls of a tank being thin and elevated well above the ground dry out with great rapidity. This drying out is, I believe, much more rapid than in the specimens used in the experiments on which we rely for our information regarding shrinkage. In the experiments conducted by Franklin R. McMillan (U. of Minn., 1915), and by Torata Matsumoto (U. of Ill., 1921) ultimate shrinkage was shown to reach 0.00065. Both sets of experiments practically agree as to ultimate shrinkage and as to rate of shrinkage. But we do not need to assume ultimate shrinkage to see how important the matter of shrinkage is in a structure designed for water pressure.

We can get a clear idea of the magnitude and importance of the cracks that will appear in a body of reinforced-concrete by comparing its elongation with the records made in experiments on reinforced-concrete

beams. In such experiments water marks appear at an elongation of about 0.0001 and cracks become visible soon after the elongation passes 0.00025. Where an analysis shows the combined shrinkage and pressure stresses in a tank will result in elongation exceeding 0.00025 then the resulting cracks will be serious. Such cracks will require the application of elastic waterproofing and such waterproofing is not likely to be permanent. But probably the most serious result of such large elongations would be the disturbance of the bond between rods and concrete.

Suppose we examine the elongation that must occur in the side walls of the Waltham Tank. The percent of steel in this case was approximately 4.23. Take (C) the coefficient of contraction due to shrinkage at 0.0003. Assume the modulus of elasticity for the concrete at 3,000,000 and the modulus for the steel at 30,000,000. Let f_c = unit tension in concrete and f_s = unit compression in steel per square inch due to shrinkage.

$$f_c = CE_c \frac{np}{1 + np}$$

$$f_c = 266 \text{ lb.}$$

$$f_s = 6300 \text{ lb.}$$

This would exceed the ultimate tensile strength of the ordinary concrete and thus the concrete would likely crack from shrinkage alone with this high percentage of steel. Even with much smaller ratio of steel the tensile stress would be high enough so that when water pressure is applied the concrete would be certain to crack, throwing on to the steel the entire stress due to the water pressure. That is, the steel stress would change suddenly from compression of 6300 lb. in the illustration above to a tension of 12,000 and undergo a total change of 18,300 lb. corresponding to a unit elongation of 0.0006. This we know must result in serious cracks. It should also be noted that this change from the large compression due to shrinkage to the full tension under water pressure may be quite sudden with consequent shock.

A paper entitled "A New Theory for the Design of Reinforced-Concrete Reservoirs" was presented by H. B. Andrews, engineer of Simpson Bros., of Boston, before the Boston Society of Civil Engineers on Dec. 21, 1910. In this paper Mr. Andrews proposes designing standpipes with walls thick enough to resist water pressure, with the combined strength of the concrete and steel, keeping the unit stress in the concrete within reasonable limit. This was a step in advance. In the original paper I find no reference to shrinkage. In the discussion that followed the result of shrinkage was referred to. In a letter (published in *Engineering News*, Sept. 7, 1911) from G. L. Bilderbeck, discussing the new theory, we find a reference to the effect of shrinkage and also the first suggestion I have found of making the side walls entirely separate from the bottom.

Since 1912 there have been several tanks built in which the side walls were entirely free from the bottom. These tanks were provided with a

slip joint at the bottom of the wall. This joint must be water tight and still permit movement. Where this joint works as planned this design cuts out the horizontal cracks. Some of the most important tanks of this design are as follows:

Location	Diameter ft.	Height ft.	Year Built
Fulton, N. Y.	40	100	1913
San Francisco, Cal. ...	65	35.83	1913
Kansas City, Mo.	40	110	1919

I find no record of statements by the designing engineers of the tanks at Fulton, N. Y., or Kansas City, Mo., as to their behavior. In *Engineering News* of Dec. 11, 1913, there is an article written by L. N. Nishkian, Assistant Engineer, Board of Public Works, San Francisco, and H. A. Minton, Architect for the City Engineer. I quote from this article:

"The obvious purpose of the sliding joint at the base is to avoid, if possible, the cracks which have usually appeared in the past near the base of the side walls in practically all reinforced-concrete tanks of large size. . . . At the time the tank was filled unfortunately no observations were made to ascertain to what extent the joint acted. A close examination at the present time shows hair-line cracks every 8 to 10 ft., extending vertically from a point about 2 or 3 ft. from the base, extending to a height of 8 or 10 ft. No horizontal cracks are apparent. This would indicate a partial action of the joint. The cracks probably failed to extend to the bottom on account of frictional resistance and extended to no greater height on account of the tensile strength of the concrete shell.

The use of the sliding joint at the base has as yet developed no objectional features. It may be questioned as to whether or not in a tank of this height any movement will take place at the joint."

This is a brief outline of the history of reinforced-concrete tank construction in this country. If the future holds something better for us, it will be the result of what these men did and recorded.

From my experience and observation and from my study of the experience and observation of others I have formed the opinion that a logical reinforced-concrete tank should be designed in accordance with the following principles:

(1) Shrinkage stresses should be kept at a minimum, not over 14 of 1% of steel should be placed in the concrete.
(2) Concrete should not be in tension.
(3) Concrete should not be subjected to heavy shear on horizontal planes.

When these principles of design are observed, the ordinary constructor, using ordinary material, with ordinary prudence, may expect the very best of results. In other worls, the building of a reinforced-con-

crete water tank becomes a very simple problem instead of a very difficult one.

What has been said of water tanks and standpipes will apply, of course, to all circular structures subject to hydraulic or fluid pressure, such as oil tanks, pressure pipe, penstocks, etc. The title of my paper on this program refers only to water tanks and I shall confine myself to that subject.

I can best outline my methods of construction by taking an example. At Barnum, Minn., we built in 1922 a tank 20 ft. internal diameter, 32 ft. high. Approximately 75,000 gal. capacity. We first made excavations to a depth of about 5 ft. and put in a footing for the side walls. We next built the bottom of the tank which was a slab 15 in. thick, with a diameter of 20 ft. This slab was reinforced with light radial and circular rods top and bottom. This slab rested upon the ground with its outer part resting upon the footings already placed for the side walls. Side walls were then constructed 7½ in. thick, with vertical recesses at intervals 15 in. wide and 1½ in. deep. These recesses were for the accommodation of the turnbuckles for adjusting the steel bands. There were three of these turnbuckles in each band. The side walls were built in a sectional form 6 ft. 6 in. high, allowing a vertical run of about 6 ft. each day. The construction joints between the day's work were cleaned and washed before the next day's run was started. Forty-eight ⅝ in. round vertical rods, spaced about 16 in. apart, were placed in the wall. There were also three horizontal bands ½ in. round rods placed in each day's run about 24 in. apart, used as a precautionary measure in construction. The forms for the side walls were adjustable to permit them to be loosened before raising to the new position. The side walls were run in six days. This work was done in late October and during November. Temperature ranged from a few degrees below freezing to about fifty degrees. The water used in mixing concrete was heated but no other precaution taken and no heat was applied to the finished work. As soon as the side walls were complete, the work of assembling the adjustable bands began. These bands were simply placed in position and tightened sufficiently to keep them in place. These bands were each in three pieces, the turnbuckles being spaced 20 ft. 4½ in., 20ft. 4½ in. and 26 ft. 4⅛ in. The turnbuckles were not staggered. The rods were of mild steel, with an elastic limit of about 36,000 lb. and a modulus of elasticity of about 24,000,000. They were not upset but were provided with rolled threads. Our computations indicated that an initial stress of about 14,500 lb. per square inch was desired in the rods near the bottom, changing to about 15,000 lb. per square inch higher up. The rods were assembled in such a manner that the lever used in tightening the rods worked down. Three men were selected, each weighing about 175 lb., and placed at the turnbuckles. Strain gauge measurements were made at points on one of the rods and the length of the wrench changed until satisfactory readings resulted. It was found that when tightening a rod 11/16 in. in diameter, a 15 in. wrench in the hands of a man weighing 175 lb. would give the desired result. This rod

was then loosened and the work of adjusting the rods was started at the bottom of the tank. No more readings were taken until all rods were stress of 14,000 lb. per square inch. This rod was No. 18 from the bottom

REINFORCED-CONCRETE TANK WITH OUTSIDE HOOPING BUILT AT BARNUM, MINN.
20 ft. internal diam., 32 ft. high, capacity 75,000 gal.

of the tank. Readings taken on rod No. 53. from the bottom showed an average of 14,560 lb. per square inch. In adjusting, the rod was tapped with a light hammer at points between the turnbuckles. This tapping

relieved the brake action and adjusted the rods to the concrete surface with uniform stress. Our measurements indicated but slight difference between the stress near the center of the rod and that near the turnbuckle.

After the rods were adjusted a wire netting covering the entire tank was attached to the rods. The circumference of the outer forms used in molding the side walls was enlarged to permit the placing of 3 in. of concrete outside of the rods and embedding the wire netting. This outer concrete gives a protection to the rods and increases the bearing. Where a gunnite plant is available, a coating of gunnite 1¼ in. thick would be preferable to the 3 in. placed as above.

The specifications called for a concrete of one part cement, two parts sand and four parts gravel or crushed rock. It was expected to use local gravel. This was later found to be unsuited for the work and crushed rock was used. The sand was washed and very coarse with insufficient fine particles. The rock ranged in size from ¼ to 1¼ in. When concreting of the side walls began it was immediately evident that the aggregate did not contain enough fine particles to insure dense concrete with a ratio of 1:2:4. However, it was decided to use this ratio for the first day's run in order to learn what difficulties might be expected with porous concrete in this type of construction. After the first day the ratio was changed until the concrete puddled properly. The new ratio was approximately 1:2:3. After the adjusting of the bands on the lower part of the tank, 9 ft. of water was put in the tank to observe its action on the porous concrete in the lower 6 ft. This concrete, when the forms were removed, showed the rock in many places. When water was put in the tank, the lower 6 ft. section sweated to such an extent that the wall was wet on the outside. Above this, where the richer mix was used, only very slight damp spots were observed on possibly 20% of the surface. None of the construction joints leaked. After allowing the concrete to be thoroughly soaked the water was drawn off and the inside of the tank wall given a brush coat of "Ionite," and followed by a brush coat of 80% cement and 20% "Ionite." Both coats were put on with paint brushes and but very little left on the surface. After a few days the tank was again filled and found to be absolutely dry, not a single damp spot appearing.

The tank was entirely filled before the outer coating of concrete was placed to permit of measuring the ultimate tension in the rods. This ultimate stress measured 16,500 lb. per square inch.

Five per cent of hydrated lime, by bulk, was used in all concrete.

The next day after the tank was completed it was filled to its capacity and left three days for the examination of the engineers. Not the least dampness ever appeared on the outer surface.

The engineers for the village of Barnum were Messrs. Druar & Milinowski, Consulting Engineers, St. Paul, Minn.

METHOD OF DESIGN

My method of design is as follows: The thickness of the side walls is determined by the compression due to the initial stress placed in the adjustable rods. It is shown in a subsequent paragraph that the initial stress in the bars should always be slightly under the final stress to produce a condition of zero stress in the concrete. Hence, dividing the total hoop tension, due to hydrostatic pressure, by a working unit stress for concrete in compression the minimum thickness is obtained.

In the Barnum Tank the pressure in the first foot from the bottom is:

$$62.5 \times 32 \times 10 = 20{,}000 \text{ lb.}$$

Dividing this 20,000 lb. by 400 x 12 gives a minimum thickness of a little over 4 in. But this would be too thin for construction purposes. It was also desirable in the Barnum tank to use a small unit since the work was to be done in cold weather and we would be obliged to place the bands on the concrete when only a few days old. We therefore made the side walls 7½ in. thick except where the turnbuckles were to come, at which points the walls were made 6 in. thick.

The next step was to determine the size and spacing of the rods. Since the rods were to take hydraulic pressure at a working stress of 16,000 lb. per sq. in. we require 11/16 in. round rods, spaced 3 9/16 in. at the bottom of the tank. At the bottom, where the side wall laps over the bottom slab, slightly closer spacing is desired because the pressure in tightening is exerted on the floor slab. In the Barnum Tank 11/16 in. round rods were placed 3 in. at this point. The rods above the bottom were spaced as required by the pressure, changing the spacing by 1/16 in. It should be noted that where rods are to be assembled on the finished wall very accurate spacing is possible.

The third step in design is to determine the initial stress to be placed in the rods. This stress is intended to be such as will result in substantially zero stress in the concrete when the tank is filled. The following notation is adopted for the computation of this stress:

Let A_c = Area of concrete (thickness of wall times spacing of rods).

A_s = Area of the rod

$R = \dfrac{A_c}{A_s}$

E_s = Modulus of elasticity of the steel

E_c = Modulus of elasticity of the concrete

$n = \dfrac{E_s}{E_c}$

S = Final tension stress in steel per square inch

y = Initial tension stress in steel per square inch

x = Initial compression stress in concrete per square inch.

When the rods are tightened on the empty tank the total tension in the rods must be resisted by compression in the concrete, or

$$A_c x = A_s y$$

From this equation we get by inserting R for

$$Rx = y \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Now if the initial stress in the steel is such that when the tank is filled the stress S in the rods will balance the pressure with a resulting stress of zero in the concrete; then when the pressure is released the change in the rod stress of $(S - y)$ will be accompanied by a change in the concrete stress from zero to x. But the change in length of rods and concrete must be the same. Since the change in length is the same, the change in stress in the steel must be to the change of stress in the concrete as the modulus of elasticity of steel is to modulus of elasticity of concrete or expressed alphabetically

$$\frac{S - y}{x} = \frac{E_s}{E_c}$$

By inserting n in this equation it reduces to

$$S - y = n\,x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From Equations (1) and (2) we get

$$x = \frac{S}{R + n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$y = \frac{RS}{R + n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Equation (4) gives the initial stress desired, y, in terms of R and S, which are now known and n which must be estimated from the character of the concrete which it is proposed to use.

In the tank under consideration we have an $\frac{11}{16}$ in. rod and the spacing is $3\frac{9}{16}$ in. on the wall $7\frac{1}{2}$ in. thick. A_c is then 26.82, A_s equals .3712, S equals 16,000, E_s was taken at 24,000,000 and E_c estimated at 3,000,000, giving $n = 8$.

This gives us 14,400 lb. per sq. in. as the proper initial stress to put in the rods. As pointed out previously, the initial stress varied from our computed stress but little. The final stress was slightly larger than the computed final stress due to the large value of n in the green concrete.

It may be well to point out here that while n must be estimated in advance of any definite information as to its value as in the design of all other types of reinforced-concrete construction considerable variation can be made in its value without materially affecting the results. For example, in the tank under consideration had n been assumed at double the value above, namely, $n = 16$ and had its true value later been found at 8, the condition of stress instead of being 16,000 lb. per sq. in. in the

steel and zero in the concrete, as assumed in the design, would have been 14,900 lb. in the steel and a tension of 18 lb. per sq. in. in the concrete. Thus, it will be seen that even with the large difference assumed the resulting tension in the concrete is only nominal. Should the value of n chosen prove to have been too small it means the reverse of the above conditions. As it is our purpose to avoid tension in concrete, it is better that the value of n should always be taken too small rather than too large.

I do not propose, of course, in actual practice to measure the stress in each rod. My experience with tightening the adjustable rods indicates that a rod may be tightened to a predetermined initial stress by adjusting the length of the wrench to the size of the rod and the weight of the man. Since the man always tightens the rod with the wrench working down, and is supposed to put his whole weight on the wrench, very close results may be obtained. Small variations may be expected. In order to show that even great variations will not defeat the purpose of the design, I have assumed a variation in the initial stress of from 10,000 to 20,000 lb. per sq. in. as applied to the Barnum Tank.

The rods in the tank were $\frac{11}{16}$ in. round for the lower 16 ft. of the tank and $\frac{9}{16}$ in. from that point to the top. The $\frac{11}{16}$ in. rods were spaced from $3\frac{9}{16}$ in. at the bottom to 7 in. at a point 16 ft. from the bottom. The $\frac{9}{16}$ in. rods were spaced $4\frac{3}{4}$ in. just above this point and were spaced 14 in. at the top. Table 1 shows the results of tightening the different rods 10,000 lb. per sq. in. and 20,000 lb. per sq. in. It also shows results of the value of n at 8 and 15. The m in the table is the stress per square inch left in the concrete when the tank is full. The plus sign indicates compression and the minus sign tension.

A study of this table shows that even with extreme carelessness in tightening the rods or with a wide variation in the value of n the resulting conditions are far from serious.

Spacing, in.	Ac	As	y	x	n–8		n–15	
					S	m	S	m
$3\frac{9}{16}$	26.72	0.3712	20,000	278	22,224	+87	24,170	+113
7	52.5	0.3712	20,000	141	21,128	+36	22,115	+43
10	75.	0.2485	20,000	66	20,520	+15	20,990	+17
$3\frac{9}{16}$	26.72	0.3712	10,000	140	11,120	−70	12,100	−54
7	52.5	0.3712	10,000	70	10,560	−38	11,050	−35
10	75.	0.2485	10,000	33	10,260	−19	10,495	−18

As to the cost of this mode of construction, I am of the opinion that tanks of considerable size can be built under this method cheaper than under the old method. The fact that we are able to use steel at a high unit stress saves materially in the weight of the steel. By the use of rolled threads the price per pound is advanced but a trifle. The total

cost of the bands under my method is materially cheaper than under the old method. The assembling of the bands is at least as cheap as under the old method and the tightening is more than compensated for by the saving in placing concrete in the walls without being bothered by the horizontal hoops. In structures of any magnitude the saving in concrete would be quite material, as the old method called for the side walls to be made thick enough to take the pressure within the elastic limit of the concrete in tension. My method requires only sufficient thickness to carry in compression a load slightly less than the hoop tension due to pressure. The problem of water-proofing under the old method was a very serious one. Under my method rich concrete will not require water-proofing and porous concrete can be water-proofed at a small expense.

In the Barnum Tank 7½c. per sq. ft. was spent on the waterproofing of the inner surface. The total cost of the 3 in. outer coating, including the wire netting, was 18c. per sqare foot. The assembling and tightening of the adjustable hoops cost about $20 per ton, which is but a trifle in excess of the cost to us of assembling horizontal rods in tanks built under the old method. The most important feature is the production of a logical structure with all material well within the elastic limit. Such a structure should be permanent. Where a tank is built with the stresses in concrete beyond the elastic limit in tension we not only have a serious problem in making such a structure hold water but we must have greater doubts of its permanency.

A logical solution of the peculiar problems that have confronted the builders of concrete structures of this character in the past should open a wide field for the use of concrete. If we examine the sky line of any large city like Chicago we will see wood tanks by tens of thousands, many of them on concrete supports. The final solution of the small roof tank and the wayside water tank of the railroad will probably be the premolded tank. I hope to devote some time this coming year to the solution of this particular problem. In my opinion, the ultimate solution of structures subject to hydraulic pressure must be largely by the use of reinforced-concrete.

Design of Elastic Structures from Paper Models.

By George Erle Beggs.*

This paper is supplementary to the one on a similar subject given before this Society a year ago. †

My purpose here is *first*, to present additional evidence of the correctness of the results obtained from the deflections of paper models; and, *second*, to indicate some of the practical uses of the model method of analysis.

Celluloid Structures.

The celluloid structures shown in Fig. 1 to 11 are designed from the results obtained from *smaller* paper models. By use of a measuring microscope and special gages, as described a year ago, the reactions of these structures were completely determined for various conditions of loading. As is well known, a reaction is completely defined when its magnitude, its angular direction, and a point through which it acts are known. If the reaction is taken by a hinge, the point of action is through the hinge, and only the direction and magnitude of the force must be determined. If any reaction of an elastic structure is correct in position, direction, and amount, such single reaction applied at the support of the structure will produce both static and elastic equilibrium.

In Fig. 1 is shown a two-hinged arch of a few feet span mounted on a board and supporting a 1.5 lb. lead weight. The right end of the arch rests on a hinge pin and the left hinge is supported by an aluminum link fastened to the board by a single pin at its upper end. The arch has come to rest under the application of the 1.5 lb. load, and is therefore in *static* equilibrium. But note that the left end of the arch is deflected away from its normal unloaded position, showing that there is not *elastic* equilibrium. The link was intentionally placed on the wrong reaction line.

Again, refer to Fig. 2, the direction of the left reaction caused by the multiple loading shown is along the direction of the link. The free left end of the arch is seen to move neither up nor down from its normal position, even though the arch shows considerable deflection under the applied loads. The direction of this left reaction was found by study of the deflections of a paper model, and the truth of the solution is established by the elastic equilibrium of this larger celluloid structure.

In Fig. 3 is shown a two-hinged frame supporting a central load. This frame was designed on the assumption that the structure was supported by hinge pins at the foot of the columns. To demonstrate the direc-

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*Princeton University, Princeton, N. J.

†"An Accurate Mechanical Solution of Statically Indeterminate Structures by Use of Paper Models and Special Gages." G. E. Beggs. *Proceedings*, American Concrete Institute, vol. 18, 1922.

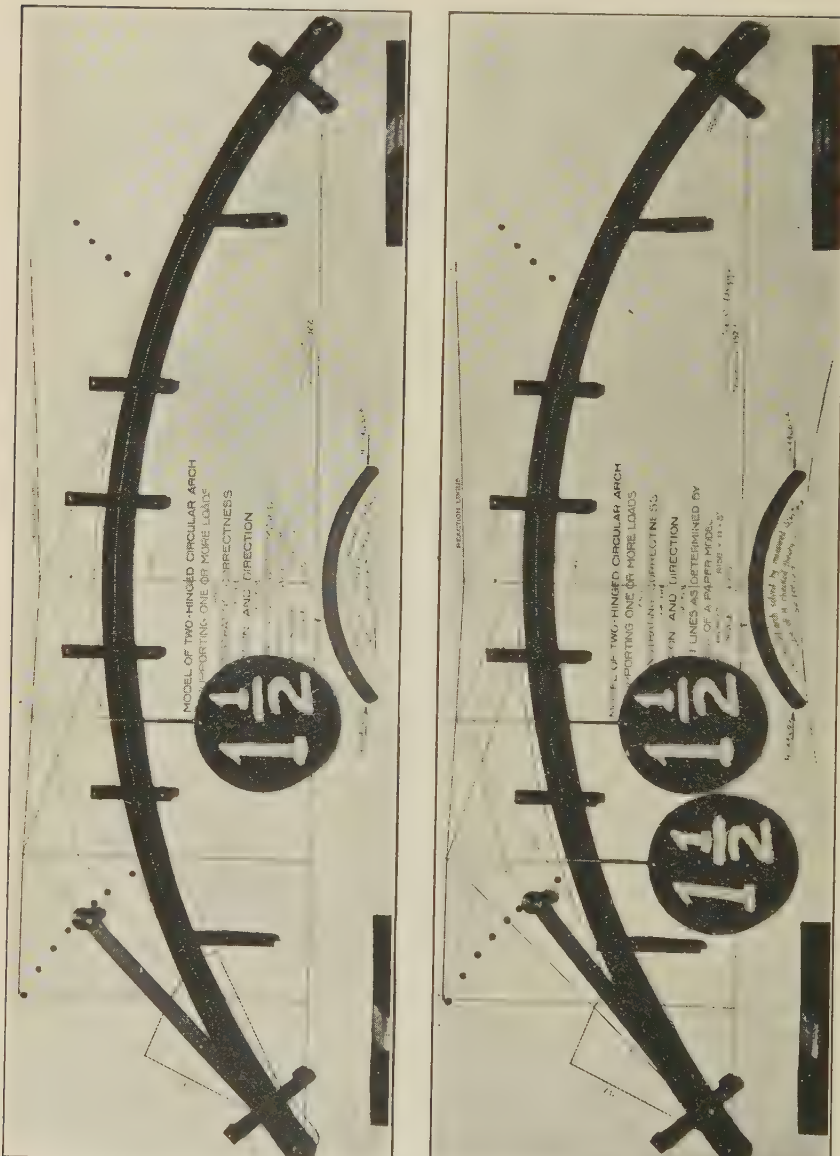


FIG. 1 AND 2.—CELLULOID STRUCTURES DESIGNED FROM PAPER MODELS.

Fig. 1 (above)—A Two-Hinged Arch with One Dependent Load, Fig. 2 (below)—Same Arch with Two Dependent Loads.

tion of the reactions, the pins at foot of columns were removed, and the structure entirely supported by two aluminum links attached to fixed hinge pins at their upper ends. The satisfactory elastic equilibrium is evident from the figure, for there is a negligible amount of deflection of the column supports from their normal geometric position.

In Fig. 4 is shown a circular ring of 9 in. radius and ¾ in. width. Test of a paper model indicated that the line of thrust was 5.9 in. from center of the ring, whereas the approximate theory gives 5.7 in. The value obtained from the paper model test was used in the design of the celluloid ring. As shown, this ring is cut at the right end of the horizontal diame-

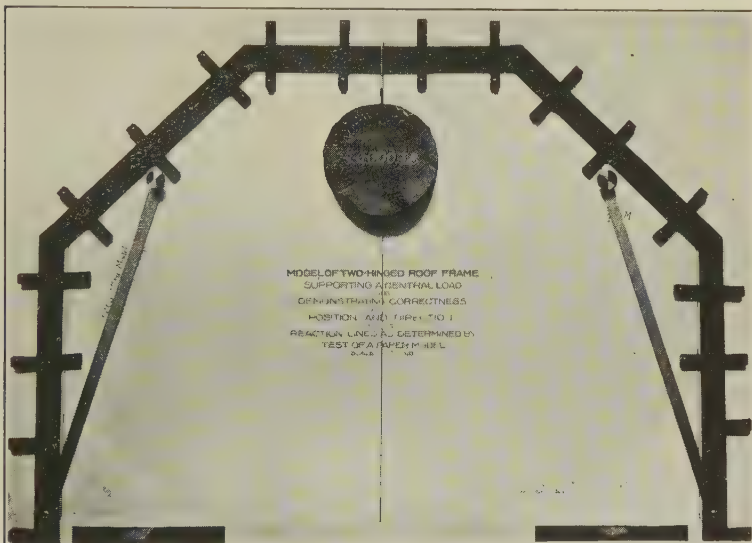


FIG. 3.—MODEL OF TWO-HINGED GROUP FRAME SUPPORTING CENTRAL LOAD.

ter, and the section extended so that a metal ring may be introduced between the cut ends on the line of thrust. The fact of elastic equilibrium is evident, for the cut ends of the ring section remain parallel to each other when the ring is loaded with the 3 lb. lead weight.

The four-post continuous portal with columns fixed at bases, as in Fig. 5, supports a single inclined load. For this loading the forces transmitted to the foundations are in path of the inclined white arrows shown. When the several foundations are supported by single hinge pins, indicated by the white circles, no rotation of the foundations occurs when the inclined load is applied to the celluloid frame. The condition of fixity of column bases assumed in the design is satisfied, and the validity of the paper model analysis is further established.

The celluloid arch shown in Fig. 6 is fixed at each end and carries a 1.5 lb. lead weight. Study of a smaller paper model showed that the paths of the two reactions are along the white arrows shown. On these reaction lines single hinge pins are placed to attach the foundations to the board. When the other pins are removed from the foundations, as shown by Fig. 7, these foundations do not rotate, for they are in both static and elastic equilibrium. If the load be moved to any other point of the arch, each foundation turns on its single hinge pin, indicating that elastic equilibrium has been disturbed.

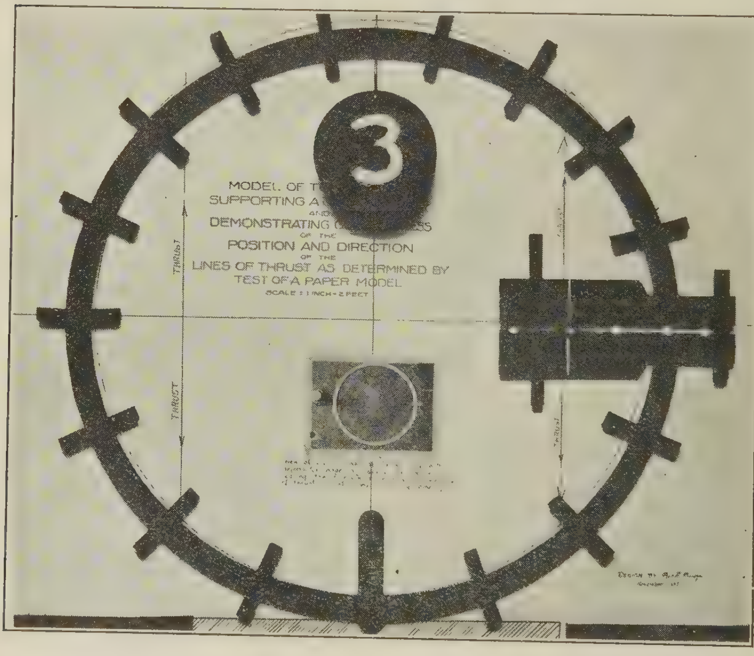


FIG. 4.—MODEL OF TUNNEL RING SUPPORTING CENTRAL LOAD.

Two weights have been hung from the same arch in Fig. 8, and for this loading the reactions are along the white lines indicated. As before, no rotation of the foundations occurs about the single hinge pins, which is in agreement with the design assumption that the arch has fixed ends.

The purpose of Fig. 9 is to show the truth of the rule that the line of temperature thrust passes through the center of gravity of the ds/I values of the arch rib. The right hand foundation is fixed and a force in the path of the white arrow has been applied to the left foundation in the line of the temperature thrust. The foundation is found to move parallel to itself as it is drawn toward the left by the single force. The effect

of a drop of temperature is thus simulated, and the position of the temperature thrust established.

The multiple arch with elastic columns in Fig. 10 is designed on assumption that columns are fixed at their bases. If a single central load on the center arch is assumed, the forces transferred to the four foundations are along the white lines shown. Single hinge pins placed on these lines fix the foundations when the 10 lb. load is placed on the center arch; and, since the column bases do not rotate about these single hinge pins, the design assumptions are satisfied.

The same multiple arch was designed on the assumption that the two right hand columns were free to turn on hinge supports, and that the two left hand columns were fixed at their bases. On this assumption the forces transmitted to foundations acted along the dotted white lines, as shown in Fig. 11. Note that the two lines at right pass through the centers of the column feet, which were assumed hinged. When the 10 lb. load is

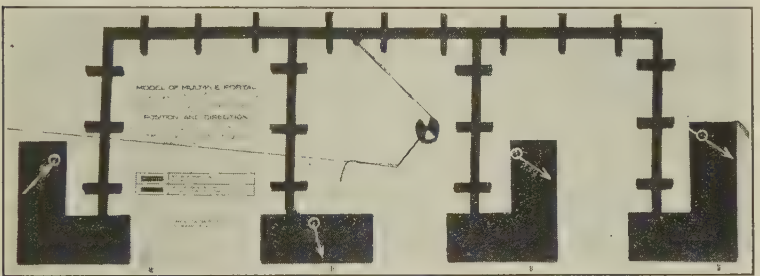


FIG. 5.—MODEL OF MULTIPLE PORTAL.

placed on the middle arch, the two right hand column feet turn, and the two left hand ones remain fixed. This accords with the design assumption, and demonstrates again the correctness of results obtained from observation of the deflections of smaller paper models.

PRACTICAL USES OF THE METHOD.

It is not the purpose here to make a defense of the use of elastic structures, such as may be solved advantageously by the use of models. The reader is urged to make his own investigations as to the economic advantage that may be seized in many cases by the selection of a continuous frame design, proportioned in its various parts according to the true distribution of forces through the structure. The principle that structures designed, proprotioned, and built as a unit are more economical than similar structures designed as statically determinate ones will meet with more favor when every structural engineer can solve a composite framework built of well connected members. The economy of an elastic continuous structure is well illustrated in the description given in *Engineering*

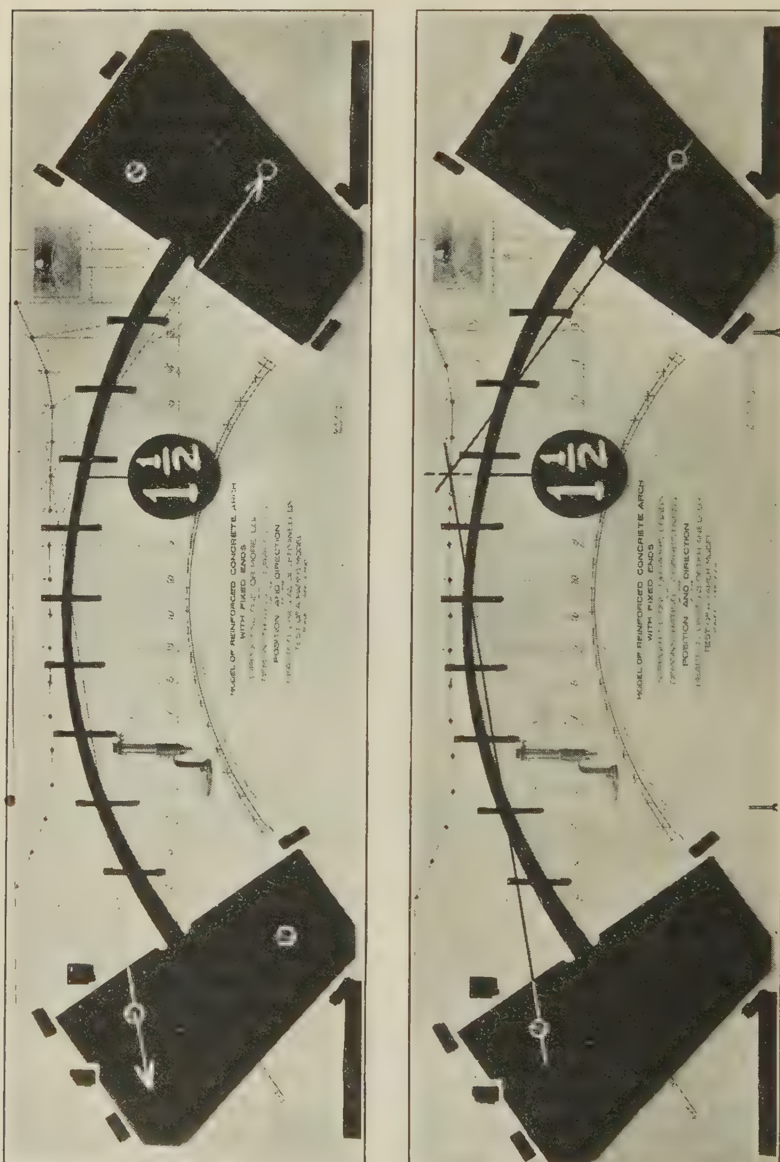


FIG. 6-7.—MODEL OF REINFORCED-CONCRETE ARCH WITH FIXED ENDS.

Fig. 6 (above)—Force of Reaction Shown by White Arrows, Fig. 7 (below)—Hinge Removed and Foundations Do Not Rotate.

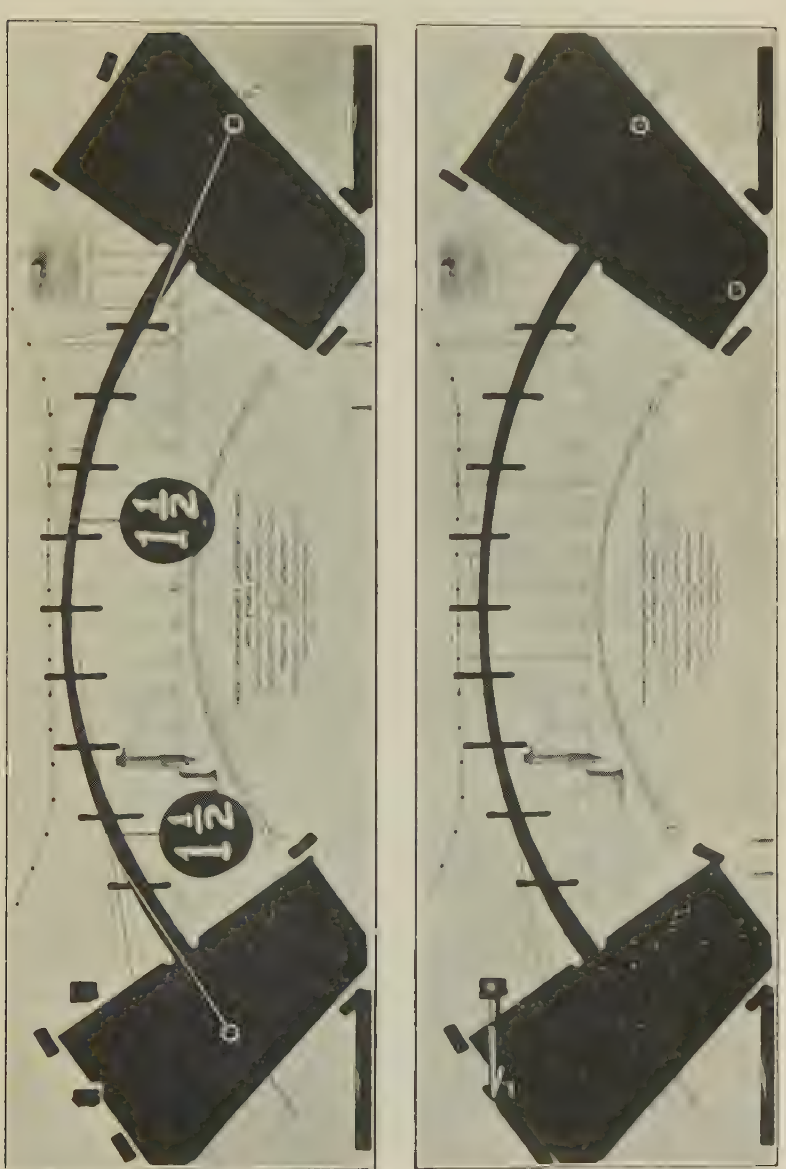


FIG. 8 AND 9.—SAME MODEL AS SHOWN IN FIG. 6 AND 7 SHOWING CONDITION UNDER DIFFERENT TYPES OF LOADING

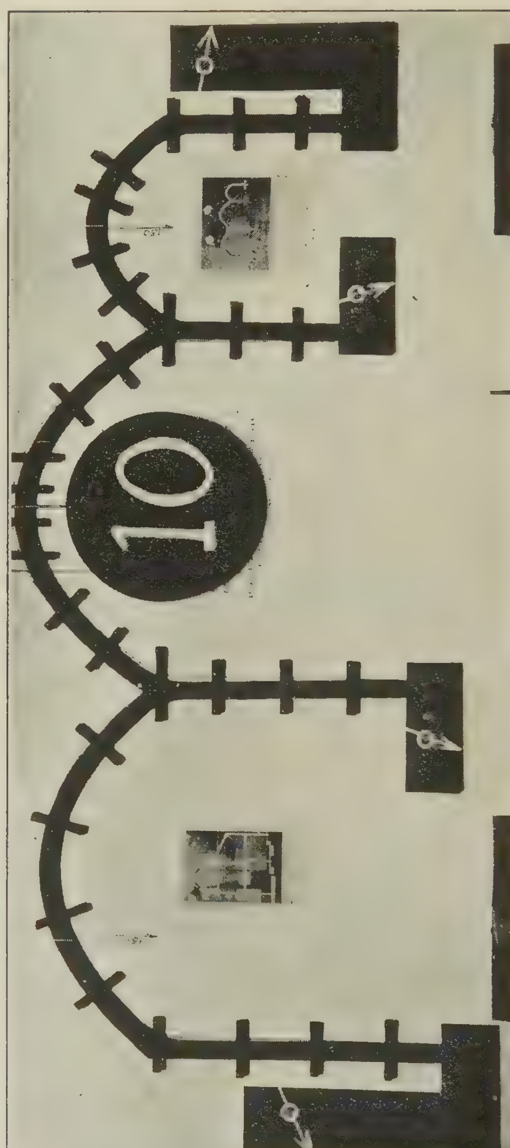


FIG. 10.—MODEL OF MULTIPLE ARCH WITH ELASTIC COLUMNS.

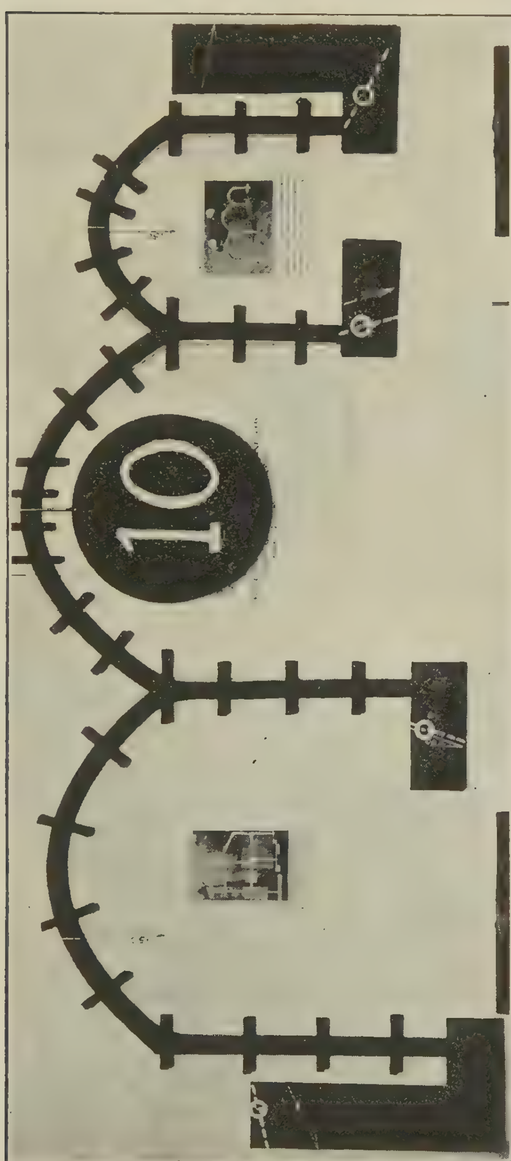


FIG. 11.—SAME ARCH AS FIG. 10 SHOWING THRUST WHEN PINS ARE REMOVED.

News-Record, Jan. 11, 1923, p. 73, of a continuous frame design for the highway bridges over the Bronx Parkway roads. The estimated overall savings as compared with the true arch design is given as $5000 per structure. This saving depended upon an engineer's ability to design the

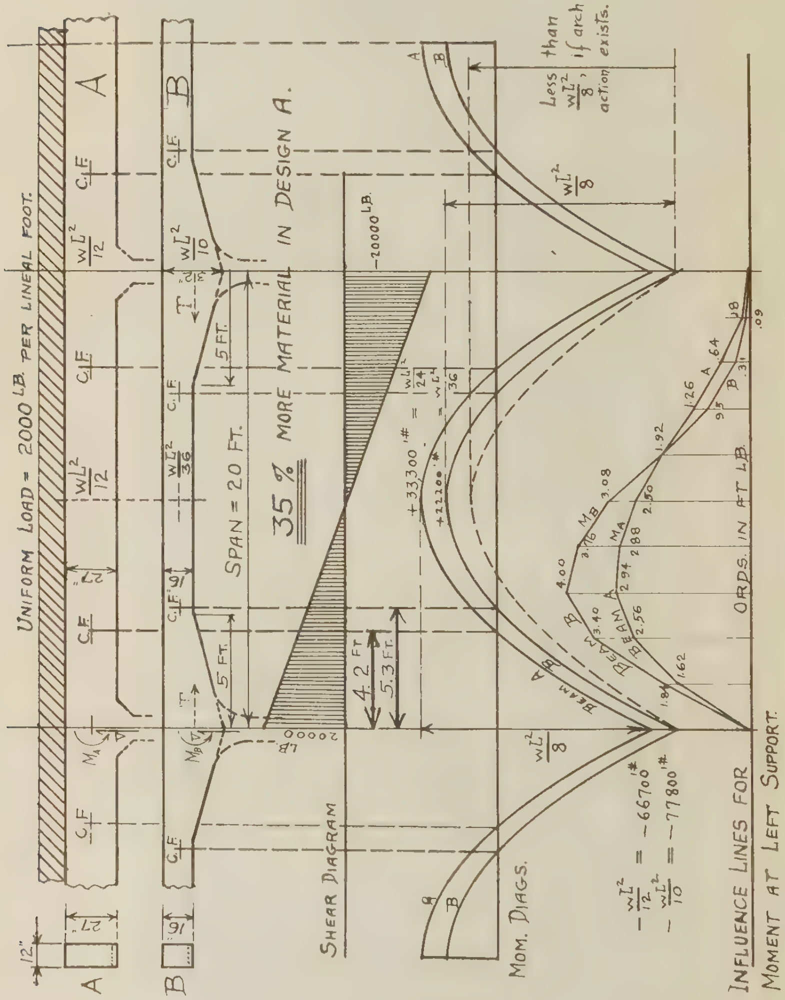


FIG. 12.—COMPARISON OF DESIGN OF CONTINUOUS BEAMS SHOWING USE OF ELASTIC MODEL.

elastic frame. Such design may be based either upon deflections determined by mathematical calculation, or by measurement of the deflections of a model structure.

In Fig. 12 is given a comparison of designs of continuous beams to illustrate the use of an elastic model and the advantage that may be

gained by employing a beam of variable section. The condition of loading is uniformly distributed and not moving. If this beam is designed of uniform section and of depth to provide for the maximum moment $W L^2/12$, it will be 12 in. wide by 27 in. deep. But let us assume that a continuous

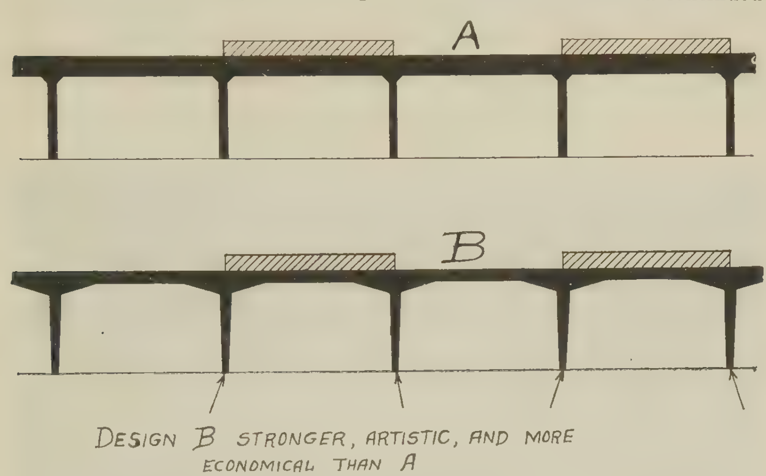


FIG. 13.—SILHOUETTE ELEVATIONS OF TWO DESIGNS SHOWING SAVING BY CONTINUOUS STRUCTURE.

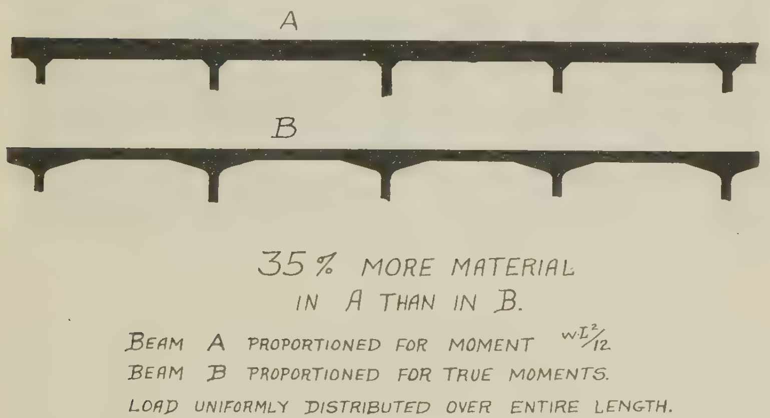


FIG. 14.—COMPARISON OF DESIGN FOR CONTINUOUS AND NON-CONTINUOUS STRUCTURES.

beam of variable section may have some advantage for the reason that both the moment and the shear are largest at the supports of a continuous beam. We will try a beam twice as deep at supports as at center and with section uniformly varying to the quarter points. The influence line for the

moment M_b at the left support is found by making a paper model of these proportions, attaching gages at either end, introducing a small rotation at left end of model, and reading the vertical deflections of the model beam. These deflections are proportional to the influence line ordinates, and the influence line for moment at left support so determined is drawn in Fig. 12 for Beam B. The influence line for end moment of Beam A was plotted from values taken from published tables. It is seen that the area under the influence line for B is much greater than for A. With a distributed load of 2000 lb. per lineal foot, it is found from the influence line that the

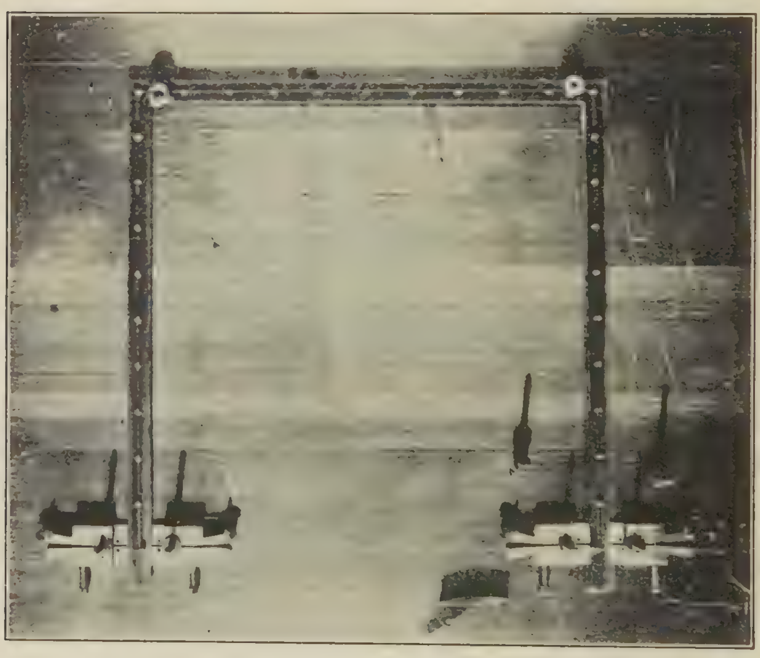


FIG. 15.—VIEW OF MODEL UNDER OBSERVATION.

moment at left end of Beam B is 77800 ft. lb., and at center 22100 ft. lb. Using the center moment as figured, the required center section by the customary method of design is found to be 12 in. wide by 16 in. deep. The end section is then assumed to be 12 in. wide by 32 in. deep, which section is found adequate with a moderate amount of steel reinforcement. On account of the greater depth of Beam B at the support, the matter of shearing reinforcement of this beam is less serious.

In Fig. 13 are shown silhouette elevations of the two designs, from which a saving of concrete is evident to the casual observer.

In Fig. 14 the advantage of variable section columns for multiple portals is illustrated. The columns in the two designs have same amount

of material, but in design B the section is increased from bottom upward to take care of increased moments caused by inclined reactions at column foundations, as occur when live load is not uniformly distributed or when horizontal forces are present. It is suggested that further study of designs A be compared with designs B to determine the relative economy of the latter when moving loads must be provided for.

Recent Progress in Method.

To save time in reading the deflections of many points of a paper model under test, resort has recently been made to photography and the use of double exposure on a photographic plate.

In Fig. 15 is shown a reproduction to reduced scale of such a photograph. The right support of the portal has been moved horizontally. The paper of model is black with white center lines or other measurable reference marks. It is thus possible to record on the photographic plate the deflections of all points of the model caused by a motion of the support, and these deflections divided by the deflection of the support are influence values for the reaction. This process of recording displacements on a photographic plate has long been used in astronomical work.

Economy in Rigid Structures.

Comparative studies of a number of statically determinate structures and indeterminate rigidly connected frames lead me to believe that frames which are rigidly connected member to member support their loads with minimum effort. The deflections under loads decreases as the rigidity of the structure increases, the external work done by the loads is correspondingly less, the corresponding internal elastic energy to be stored up by the stresses is equally reduced, whence smaller areas, saving of material, and reduction of cost of the structure follows. The work that a structure must do in supporting its loads is not only divided among all members of a rigidly connected structure, but the total work to be done is less by reason of the rigidity. The adage, "In union there is strength," applies to structures as well as to human affairs, and we might extend the application of the adage in either case to, "In union there is strength and economy."

DISCUSSION.

Mr. Richart. F. E. Richart.—I should like to say that I have used the paper model test during the past year, with very satisfactory results. There is a similar scheme that I have found very useful in studying the effect of kneebraces in stiff portal frames. Instead of using paper models and a microscope, cast-steel models and micrometer dials were used.

The models tested were two-hinged rectangular bents or portal frames, 4 ft. high, 2½ ft. wide, and 2 x 2 in. in cross-section. Three models were used, each having a different shape of kneebrace at the junction of columns and cross girder. Since they were of cast steel, all were annealed before use in order to eliminate shrinkage strains.

The object of the experiments was to determine the effect of the various kneebraces upon the horizontal reactions at the column bases due to vertical and horizontal loads on the portal. By moving the bases of the columns apart a known distance and measuring the deflections of all points of the frame by means of Ames micrometer dials, relative deflections throughout the frame were found and thus influence lines for the horizontal reaction were determined after the method described by Professor Beggs. Since a movement of 1/1000 in. could be read directly on the dials and a movement of 1/5000 in. estimated, the accuracy of measurement with these large frames is comparable to that of Professor Beggs' deformeter gages used in his work.

After determining influence lines for any loading, a few direct measurements were made of the horizontal thrust developed by a load on the top of the frame. The portal was placed in a small testing machine, with one column hinge pin held stationary and the other supported by vertical and horizontal compression links. The horizontal link transmitted the thrust through a system of levers to a scalebeam so that the amount of thrust could be weighed. When a known load was applied at the top of the portal, the column bases were kept a fixed distance apart by means of a micrometer, and the horizontal thrust then observed. As may be expected the results thus observed checked exactly with the results computed from the ratio of deflection measurements. While this experimental verification of Maxwell's theorem may seem unnecessary, it is convincing to any one unfamiliar with the fundamental nature of the theorem.

I mention this use of steel frames because of the fact that tests of a miniature model of an arch, frame or continuous beam always form a very convincing check on computations, and especially so when the model can be made of the same material as the structure to be designed.

Reinforced-Concrete Pipe for Transmission of Water Under Pressure.

By W. G. Chace.*

As a staple reinforced-concrete pipe is made by the wet process for sewers, culverts, caissons, etc. It was introduced in America for delivery of water for irrigation and for municipal, domestic and power supply, first by suggestion of an engineer who had been favorably impressed with its characteristics. The first design was a special development or outgrowth of sewer pipe designs as to unit lengths, wall thicknesses and location of reinforcement, modified in simple detail to accommodate more rigid requirements as to water tightness, flexibility and temperature changes to be met. It has been successfully applied for several years in the United States and Canada; a gradual increase in length of unit and a series of developments of joints followed as a natural course. Many important cities now depend upon this class of construction as a link in their system of water supply for domestic uses.

At first applied to lines for conveying of water under moderate pressures, i. e., under 100 ft. of head; it is now applied to pressures of over 200 ft., viz., by the U. S. Reclamation Service for supply of irrigating water, and by this company under similar pressures. It is now offered for either gravity or pumping lines under all pressures ordinarily met with in municipal domestic supply systems.

It is not usually made in sizes smaller that 15 in., and has been made in all usual diameters up to 108 in. At first made in units of 4 ft. length, it is now built most frequently in units of 10 ft. and 12 ft. lengths.

Dependable.—While in service a well-designed and built reinforced-concrete pipe cannot be so destroyed by rise of pressure as to allow all the water to escape—or the pressure at the point of delivery to fall seriously below normal. Such a pipe is a body of dense concrete within which is a net work of steel worked at low stresses. A surge of water pressure may temporarily tear the concrete by setting up extraordinary stresses in the reinforcement, but a section of pipe wall is never blown out nor is any large portion of the conveyed water allowed to escape. Rarely would the steel be so stressed beyond its elastic limit, and in nearly every case the loss of water would cease when the moment of temporary extra water pressure had passed. This feature is of immense advantage in ensuring the hourly continuity of municipal supply—minimizing fire risk, sanitary risk and commercial loss.

High Capacity.—The interior surface of pipe units is smooth, having been molded against smooth and oiled steel forms. The interior of a pine line of reinforced-concrete is continuously smooth, even at the joints,

*Lock Joint Pipe Co., Ampere, N. J.

and there are no projecting obstructions, transverse grooves, nor irregularities of line or of diameter such as would set up eddies in the flowing stream and would reduce the capacity of the line.

Bulletin 852 of the United States Department of Agriculture discusses this subject under the title "The Flow of Water in Concrete Pipe." On several pages the author indicates the superior smoothness and high capacity resulting from the use of oiled steel forms. The use of reinforced-concrete pipe in transmission mains results in small losses of pressure and in highest delivery pressures.

Losses of Water Are Relatively Small.—The walls of well-made reinforced-concrete pipe, built of a rich mixture of cement and selected aggregate, are of low permeability and lose water under the higher pressures by "sweating" only. The aggregate loss per mile is moderate and varies with the pressure of water and the age of the concrete.

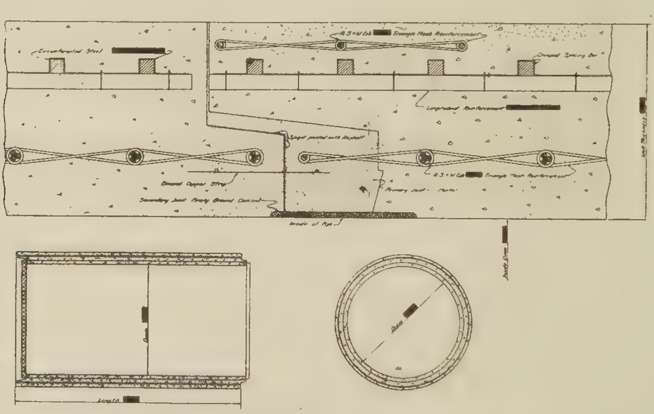


FIG. 1.—DETAILS OF REINFORCED-CONCRETE PIPE FOR HIGH HEAD.

These losses are not more than are found to exist in pipe lines of steel and of cast iron. Unlike the losses from lines of those materials, which increase with the age of the line, those occurring from concrete pipe lines are greatest at the date of the initial service, and decrease as the pores of the wall become filled.

Flexible Expansion Joints.—The importance and absolute necessity of joint devices, which remain watertight in spite of changes of length, due to changes of temperature, were not appreciated until after one or two lines had been put into service. The application of such a joint was offered to users from the first but was not insisted upon by the manufacturer of the pipe. Now all reinforced-concrete pipe offered for conveyance of domestic water supply, whether under pressure or not, is equipped with "expansion" devices in each joint. A range of temperature of 100 deg. F. will cause a variation in length of a 12 ft. pipe unit of

about 0.1 in. The types of joint offered are such that even if the temperature contraction of several pipes should appear at one place, there could be no loss of water due to the partial opening of the joint.

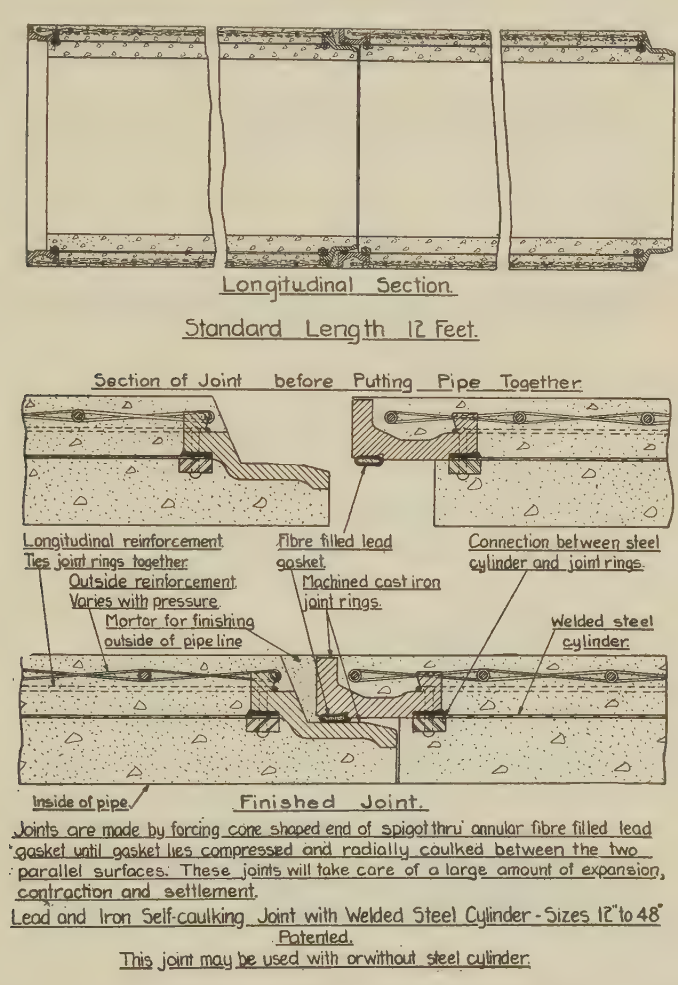
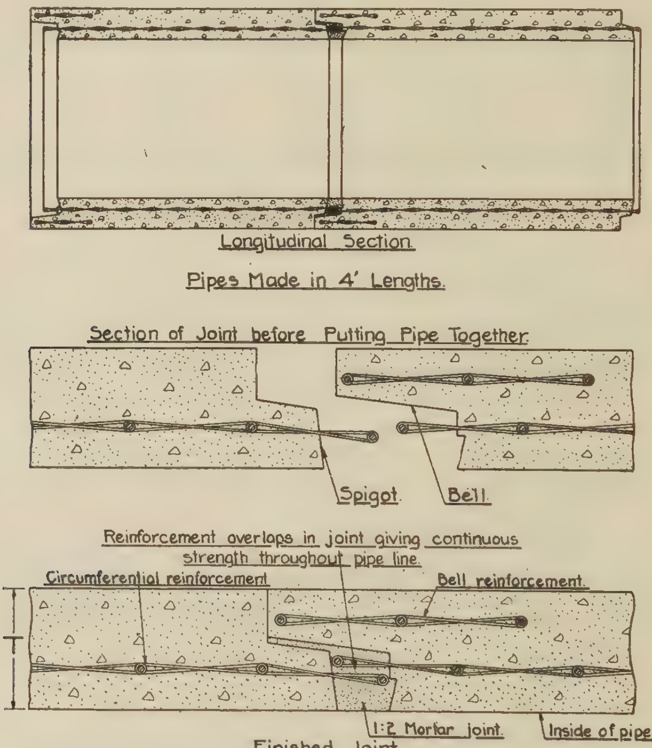


FIG. 2.—LEAD AND IRON SELF-CALKING JOINT WITH WELDED STEEL CYLINDER. SIZES 12 TO 48 IN.

Two general types of expansion joint are offered. The one type, the "copper joint," consists of a beaded copper ribbon secured within the spigot rim and the other edge of which is then jointed with mortar to the inner annulus of the bell after the pipes have been placed in position in the trench. (See Fig. 2.) The other type comprises an elastic fiber-

filled lead gasket, calked between smooth or machined steel surface on bell and spigot specials. This type is used in two forms—the "lead and iron" joint and the "lead and steel" joint.

Of these two forms of metal joint, the former, the "lead and iron" joint, utilizes a flanged iron bell casting having a wedge-shaped groove machined within its periphery, and a spigot casting machined to a conical



Dia.	24"	27"	30"	33"	36"	39"	42"	45"	48"	54"	60"	66"	72"	78"	84"	90"	96"	108"
T	3"	3½"	3½"	4"	4"	4"	4½"	4½"	5"	5½"	6"	6½"	7"	8"	8"	8½"	8½"	9"

FIG. 3.—REINFORCED-CONCRETE SEWER PIPE. SIZES 24 TO 108 IN.

form on its end, and to a cylindrical form immediately back of the cone and upon which the gasket rides after the joint has been made. A forced entry of the spigot of one pipe into the ring gasket lying inside the bell of the next pipe unit calks the gasket radially for its entire width and forces it into the wedge groove in the bell. (Fig. 3.)

The latter form, the "lead and steel" joint, comprises a plain band of steel of sufficient width as a bell fitting, and a special band, bearing

a conical rib, as a spigot fitting. The fiber-filled lead gasket is of special shape, is laid up as a ring within the bell rim, and, after the entry of the spigot, it is calked into position from *within* the pipe. (Fig. 4.)

The "copper" joint, the "lead and iron" joint, and the "lead and steel" joint remain watertight even though deflected by settlement of the pipe foundation or by movement of the back-filled earth.

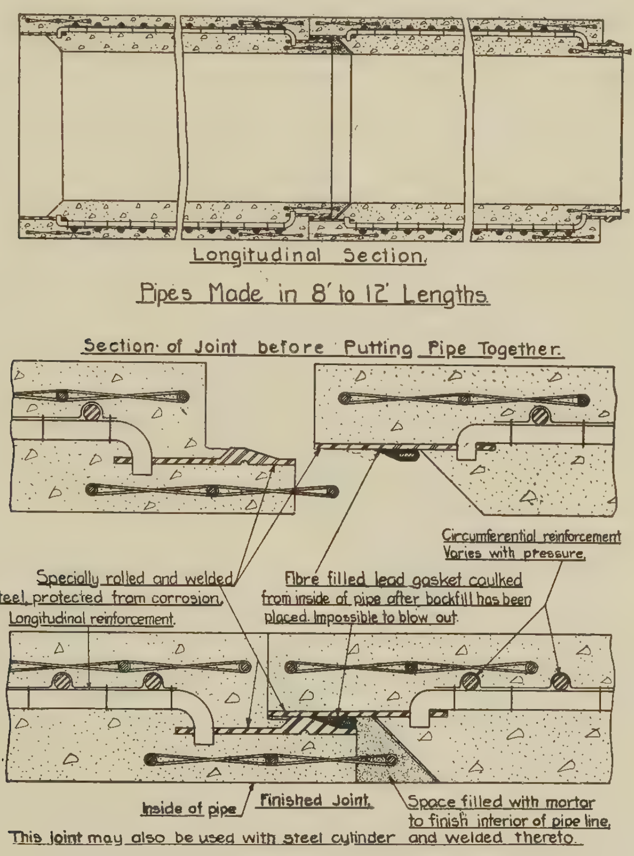


FIG. 4.—LEAD AND STEEL JOINTS FOR SIZES FROM 36 TO 108 IN.

Often advantage is taken of these designs to lay the pipe line around gentle curves of plan or of profile. For greater curvature shorter lengths of pipe are sometimes used.

The "copper" joint and the "lead and steel" joint are used within pipes whose diameters permit men to work from within the pipe. The "lead and iron" joint can be used with smaller diameters.

Inherent Strength.—Properly made reinforced-concrete pipes are *strong*, not only against the bursting pressure of the conveyed water, but also *against the pressures of the earth back-fill.* The wall is thicker than with metal pipes and the reinforcement is so distributed through the wall section as to care for earth loads. To get the maximum value of the pipe under extreme superposed loads, it is necessary that they be

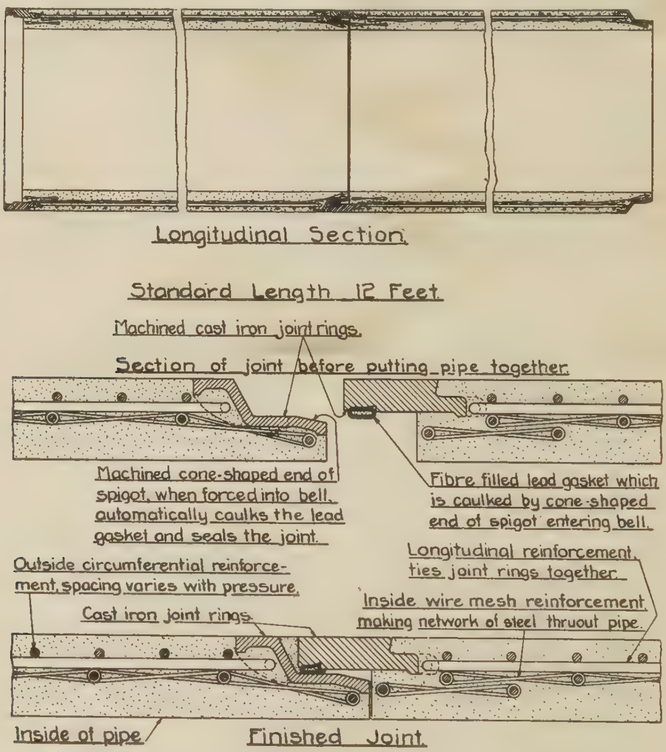


FIG. 5.—CENTRIFUGALLY MADE REINFORCED-CONCRETE PRESSURE PIPE WITH LEAD AND IRON SELF-CALKING EXPANSION JOINTS.

properly bedded and that the trench is properly back-filled. Reference is here made to the recent work of Iowa State College on this subject.

There are no initial stresses in reinforced-concrete pipe such as occur within certain metal pipes.

Permanency.—Experience has proven the durability of good concrete in all structures, especially in buried structures. Experience has also proven that the steel within good concrete, if provided with sufficient external cover, is free from corrosion, and therefore permanent.

No waterproofing, tar coating, painting or other protection is necessary, nor is there maintenance cost.

The writer has examined metal reinforced-concrete pipes after a service of over sixty years and has found them uniformly in good condition, and quite fit to repeat that period of service.

Economy.—Reinforced-concrete pipe is economical for the conveyance of water under pressure. It is moderate in first cost in the diameters in which it is offered and its maintenance cost is very low. It is manufactured of materials of low cost, sand, gravel, steel reinforcement and cement, and the labor employed is also not the most expensive. It is generally manufactured close to the site of its installation, so that freight and handling charges are kept to the lowest limit. It is laid without the use of hot lead, or of hot rivets, and therefore without the employment of high priced workmen.

Its long life means that the yearly sinking fund charges for the retirement of the bonds covering the utility may be of the smallest dimension consistent with good financing, and having in view the length of time that the line may be expected to be sufficiently capacious for the population to be served.

It is manufactured with local labor; i. e., the citizens of the community building the pipe line are engaged in its construction and their wages remain within the community. Near every community requiring such a pipe line can be found the necessary supply of sand and of gravel; and in many cases the reinforcement and the cement are of local production. The money to purchase such of these as are available is also spent within the community.

Manufacturing Processes.—Lock joint reinforced-concrete pipe is manufactured by two methods: by pouring a wet mix concrete into oiled sheet steel molds, and by the centrifugal method.

"Poured" pipe is manufactured in two styles—bar or mesh reinforced pipe for the lower pressures, and, for higher pressures, using similar reinforcement supplemented by a sheet steel cylinder to reduce seepage through the necessarily thin walls of the pipe. Fig. 2 and 4 illustrate pipe reinforced with mesh and with bars. Fig. 3 illustrates the "cylinder" pipe. The former style of pipe is used where the pressure heads do not exceed about forty pounds per square inch. Where the heads are greater it is difficult to control the seepage (or sweating) of the concrete without the use of the welded cylindrical sheet steel water stop. The cylinder of steel is secured to the joint ring by watertight connection.

"Centrifugal" concrete pipe is made in diameters from 12 to 36 in., and, of course, without the sheet steel water stop. The concrete is composed of sand, cement and water, and is so compacted into the pipe as to be practically impervious. Its density may be judged when one realizes that, made by this method of manufacture, the concrete weighs 150 lb. per cubic foot. The joint rings are secured firmly to the cage of steel reinforcement.

The secret of the successful application of reinforced-concrete pipe to the conveyance of water under pressure lies in the provision of proper joints which will predetermine and localize and certainly care for the contraction of length which follows a fall in temperature of the water carried. The phenomenon of contraction is certain to appear. The frequency of transverse shrinkage cracks in a continuous concrete pipe depends upon the cross section of the member and upon the friction of the surrounding soil. Proper joints at regular intervals prevent injury to the pipe walls, and, fixing the positions for the relief of contraction stresses, these joints prevent escape of water at those points.

In spite of great care in the preparation of the trench floor, and no matter how carefully the earth backfill may be placed, there frequently occurs a settlement of foundations or a movement of trench walls which would fracture a continuous pipe of concrete. The provision of flexible watertight joints between individual units of precast pipe is necessary for the protection of the line against such injury and ensures its water-tightness even with deflection or movement after the laying and jointing shall have been completed.

Centrifugal Process.—The processes of manufacture are simple. An outside watertight steel form properly equipped with end rings, and within which has been placed the cage of reinforcement bearing the joint fittings, is rotated at high speed; the concrete matrix is fed uniformly throughout the length of the mold, and, while still rotating, the inner surface is cleaned up and trued.

The pipe unit is then cured with steam for one day within the molds, and for one or two days after the mold is removed. It is very important that the subsequent curing shall continue without the drying out of the interior of the pipe, and care is taken to ensure this feature.*

Reinforced-concrete pipe has now been carried through the development stages essential to fit it for the successful transmission of water under pressure. Its inherent characteristics are all desirable for this purpose, and the various designs of pipe units are such as to adopt it to the various conditions under which it must serve.

Centrifugally made concrete pipe, like that manufactured by other processes, can be a success only when equipped with scientifically designed and accurately made joints, firmly secured within the body of each pipe section. (Fig. 5.)

Reinforced-concrete pipe made by centrifugal process is only now on the market in America. The basic difficulties in its design and manufacture have been successfully overcome and it is offered for the construction of domestic water supply lines under the pressures most commonly met either in gravity or in pumping systems.

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*For a detailed description of the manufacture of reinforced-concrete pipe by the centrifugal process reference is made to *Engineering News-Record*, Nov. 16, 1922, p. 829.

Developments in Surface Treated Concrete.

By Robert F. Havlik.*

I feel I can discuss the developments in surface treatment of concrete without bias, because of the fact that at Mooseheart we make use, or have made use of practically all the known processes of surface treatment of concrete. Our primary business is to educate dependent children and teach them a useful trade in order to make them self-supporting when they graduate from our high school. The manufacture and sale of concrete products is but incidental to this great work.

Among the many trades that we teach at Mooseheart is that of the manufacture of ornamental concrete. By this term we mean decorative concrete for building purposes and decorative purposes in parks, gardens, etc. We naturally include some instruction in the manufacture of plain concrete trim stone and concrete blocks, but we do not spend much time on these because we feel that any man who is competent to manufacture high grade decorative building stone is also competent to manufacture the plain trim stone, concrete building blocks and other similar products. That part of the work can be taught a student in a few weeks at most, but it takes several years to turn out a first class mechanic qualified to make models, molds and the finished concrete products.

The principal products that we "sell" are our graduates, if you will pardon this expression, and the only selfish motive that I have in discussing this subject is the hope that concrete products plants will add trim stone departments to their business, and thus provide additional positions for competent men who are thoroughly trained in this work.

As stated above, at Mooseheart we use practically every known process of surface treatment, using whichever is best suited to the particular job at hand. Because of the fact our boys are likely to work in plants using any of the better known methods we must train them in all. Each method of surface treatment has its own peculiar advantages and oftentimes several methods can be used to excellent advantage on the same job—at least, that has been our experience.

In the course of this discussion and the demonstration which is to follow I will mention many little details which are usually regarded as trade secrets. You who have investigated the subject have doubtless found that many a manufacturer is very reticent to discuss just how he treats his molds, what ingredients he uses and other things which make for success or failure. I well recall that I visited several ornamental stone plants before I learned how glue molds were treated to prevent undue disintegration. We have no secrets to hide, and always welcome visitors to our plant, and will always cheerfully furnish any information pertain-

*Moosehart, Illinois.

ing in any way to the manufacture of high grade ornamental concrete. On several occasions we have had men who are engaged in this business spend a few days to several weeks in our plant learning something about the details of the work. This usually pertains to the manufacture of models and glue and plaster molds.

The selection of concrete blocks and trim stone for all the permanent buildings at Mooseheart was a very significant occurrence and a tribute to the enduring and pleasing qualities of this product. Mooseheart is thronged throughout the warm months of the year with visitors, principally members of the order, from all over this country and even in the colder weather hardly a day passes but that we have several visitors. Practically every visitor to Mooseheart becomes an enthusiastic believer in surface treated trim stone and building blocks before he leaves. We attribute this high regard for our building material to the fact that nearly all of our buildings are constructed of surface treated concrete blocks and trim stone. All the blocks used in our buildings are surface treated and are faced with crushed granite. The trim stone used in the buildings up to 1916 was made with a smooth surface of white cement, white sand and white marble. This checked more or less, but since 1916 the trim stone also has been made of surface treated concrete faced with crushed granite and white portland cement. From 1913 to 1916 gray cement was used in the blocks and white portland cement in the trim stone, but since 1917 both blocks and trim stone were faced with white portland cement. The granite used is known as "Crown Point Spar." Numerous visitors from the east, where granite is used much more commonly than in the central states, have remarked that our product is just as attractive as the natural material. One group of men, when examining one of our buildings, thought it was natural granite and wondered how we could use it so far from the source of supply, and was greatly surprised to learn it was surface treated concrete instead.

What has been done at Mooseheart can be done in any of the larger cities in this country. I find that architects, as a rule, are highly in favor of good concrete, but do not use it to any great extent because they cannot find competent manufacturers to furnish it. But for surface treatment of concrete, concrete blocks would be doomed for use in foundations under inexpensive buildings and for backing up in high grade buildings. Surface treatment has done more to promote the greater use of concrete in various forms than any other one factor. Therefore, too much stress cannot be laid on the importance of producing attractive surfaces in both mass concrete and concrete products.

My remarks pertain principally to surface treatment of concrete products but can be applied also to mass concrete.

Requirements of Good Product.—In order to find a ready sale for concrete products they must meet three requirements:

1. Be sufficiently strong for the purpose intended.
2. Must have an attractive appearance.
3. Must stand outside weather conditions without checking or crazing.

In the larger cities the building ordinances protect the consumer on the strength requirements. The customer can determine for himself the attractiveness of the product, but he cannot so easily determine whether or not the product will stand outside weather conditions without checking or crazing. The only products known today that will not hair check are those that have been faced with selected aggregate, containing no dust or fine material below about a No. 20 mesh, and have been surface treated. The manufacturer who can guarantee his product to meet all three of these requirements can do a volume of business that will only be limited by the capacity of his plant. Modern machinery and the comparative low cost of cement and concrete aggregates as compared to other materials make it easy to compete with other building materials.

During the next few years we will undoubtedly enjoy the biggest building boom that this country has had in the last fifteen to twenty years, so manufacturers will do well to market a product at this time which will meet these conditions, and in later years, when times may not be so good, it will be the best sort of a guarantee as to the quality of their product.

It has been a very common practice to imitate Bedford stone, and in doing so manufacturers have been tempted to use white silica sand and other similar fine material. The result has been that when made into trim stone the product has invariably checked to a greater or lesser extent —usually to a very great extent. Stone of this character hurts the industry beyond measure.

A surface which has been treated to expose the aggregate will not check, providing no fine material has been used in the facing. By "fine material" I mean dust and all material that will pass a No. 20 screen. If the owner or architect insists on a surface that would be smoother than what would be produced by material of this character the wise manufacturer will let his competitor take the job rather than run the risk of the surface of the material checking and thus hurting his reputation. Although it is true that stone has been made with finer material than the above without checking, it is the exception and not the rule, and only goes to prove that finer material had better not be used in the facing. The best results will be obtained by using specially selected coarse sand and fine pebbles, crushed granite and other similar aggregates, from which all dust and fine material has been removed.

For our regular building blocks and trim stone we use one part of white portland cement to one part each of Nos. 3, 3½ and 4 Crown Point Spar. For lamp posts we use one part cement to one part each Nos. 3, 3½ and 4 Crown Point Spar and one-half part of crushed pink granite. These mixtures produce stone which positively will not check when exposed to outdoor weather conditions, regardless of the process used in producing the stone, it being understood, of course, that in all cases we expose the surfaces of the aggregate by some special treatment, which I will describe later.

For garden furniture we use similar mixtures, sometimes substituting

a little crushed white marble for some of the Crown Point Spar, and occasionally using the next smaller size Crown Point Spar if the ornaments on the article have very fine detail. We refrain, however, as much as possible, from the use of the finer aggregates.

We have always treated the surface of our blocks, but for the first few years we made our trim stone with a smooth finish similar to that of Bedford stone. Most of this stone checked considerably. In 1916 we started treating the surface of both the trim stone and blocks, with the result that since then we have eliminated hair checking entirely in all of our trim stone. The blocks never hair check. It is a peculiar fact that blocks produced by any process will seldom check on the surface, regardless of the type of surface produced and facing material that is used. Yet the same facing material, if used in trim stone, will cause considerable checking. There are many theories for this—the most common of which is that in manufacturing trim stone—especially when made by the tamped process, the workman is likely to smooth the stone with a trowel, and thus bring an excess of cement to the surface, which ultimately causes hair checking, but frequently the same material that will not cause hair checking in blocks will produce hair checks in cast stone, which would seem to contradict the idea that the checking is caused by troweling the surface of the stone. The safest procedure is to avoid the use of the fine aggregates entirely, and treat the surface of all products. The surface produced is the most pleasing obtainable, and will build up a permanent future for such products.

Market for Surface Treated Products.—Ordinary concrete products for building purposes can only compete with common clay brick, and then frequently only in appearance and not in cost, for in some localities clay brick are sold for less money than good blocks can be produced for. Such blocks look better than common brick, but can hardly be said to look as good as even the cheapest of face clay brick. For this reason the profit on such products is not great. The surface treated products are so superior to ordinary concrete products that there is no comparison between the two. The logical market for such products is in competition with the very best grade of brick, terra cotto and cut stone. For that reason the profit against such competition is big, and the manufacturer can afford to make a high grade product that will be above criticism at all times. The field for these products is unlimited, because masonry buildings are becoming more common daily, and usually high grade pressed brick, terra cotta and cut stone are used for the facing of such buildings. The most profit to the manufacturer and the greatest saving to the user comes in the use of surface treated concrete blocks, as a substitute for cut stone, terra cotta and pressed brick. Such jobs, as a rule, cannot be converted into concrete block jobs, in their entirety, but will require the use of both concrete blocks and trim stone. For this reason it is but logical that all concrete products plants operate trim stone departments. Without such departments they must confine most of their sales to foundation jobs, and that means competition with the cheapest of competing materials.

Methods of Surface Treatment.—There are several methods of surface treating concrete products. In one method the product is usually made of cast concrete. When it has hardened sufficiently the exposed surface of the stone is ground with carborundum wheels. Special machines are made for that sole purpose. This treatment produces a very pleasing surface, and if the concrete is composed of the proper aggregates, the surface will not hair check or craze. This method is employed by three or four of the most reliable manufacturers in the eastern states. When this method is employed the product is frequently cast in sand molds, but not always.

Another method of surface treating concrete is to spray the surface of the green product with a very fine spray of water under pressure just as soon as the product is removed from the mold. The effect of this is to wash off the surface cement and drive it into the concrete, thus exposing the natural surface of the aggregate. The product is then cured until it is hard enough for use. Sometimes the surface of the product is further treated by scrubbing it with muriatic acid and water. This will brighten the surface and remove all traces of cement from the surface of the aggregate. Some prefer this to the sprayed surface because the surface is brighter. When crushed granite or marble is used in the surface the stone glitters more than if the surface has merely been sprayed and not scrubbed. In another method—particularly when the product is cast by the wet process, the stone is allowed to cure thoroughly, and is then dipped in a strong solution of muriatic acid and water. High grade garden furniture is practically always manufactured by this method. It is also found to be very economical in the manufacture and treatment of high grade trim stone—particularly when the product is highly ornamented.

The best way to build an acid tank is to make it of concrete and then line it with sheet lead. The joints in the lead have to be burned by a lead burner, as solder will not withstand the action of the acid. The lead lining should, in turn, be protected with a lattice work of thin wooden strips fastened together by wooden pegs. No metal of any kind should be used in the lining of the tank as the acid will eat it up.

Plain trim stone is usually made by the tamped process, and even though it is made very wet, such stone can be treated very economically by first spraying with water and then scrubbing it slightly with muriatic acid and water after it has been cured.

One kind of concrete block, when made with a granite or similar surface, is allowed to cure for 24 hours and the surface of the block is then scrubbed with water. This is one of the simplest and earliest forms of surface treatment, and also one of the most economical. This method, however, only works well with blocks that are set face down on a pallet. In practice it is found that blocks in which the face is exposed to the atmosphere while curing cannot be scrubbed in this manner with satisfactory results, apparently because the surface of the block is too hard when the back of it is sufficiently hard to stand handling, and if scrubbed earlier, the surface is too soft and crumbles at the edges. The setting

of a block face down on a pallet appears to retard the setting of the facing without having the same effect on the rest of the block, and the result is that the surface can be scrubbed satisfactorily the day after the block is made without spoiling the edges of the block.

These various methods have been used to a greater or lesser extent since the early part of the century—as far back as 1903. In my opinion, it helps considerably to spray the face of the block while it is still in the machine, or just after it is removed from the machine. In such cases the block should be scrubbed as I described above—viz.: the following day. We find this treatment reduces the cost of scrubbing, and also produces a surface that sparkles more than if it is only scrubbed and not sprayed.

Facing Materials.—Very beautiful effects are obtained by screening out the right size pebbles from specially selected sands, but unless one is fortunate enough to have his plant located in the immediate vicinity of sands that are suitable, the manufacturer is limited to the use of crushed granite and marble, because these are the only facing materials suitable for facing purposes that are being marketed on a big scale. There is no one, to my knowledge, marketing specially selected sand for facing purposes. Several eastern firms obtain a granite effect by mixing crushed marble with crushed slag in the proper proportions. One well known manufacturer uses specially selected pebbles. In the central states the material that is most easily obtained for this purposes is the crushed granite shipped in from the east, Wisconsin and Minnesota. Stone that is faced with crushed granite and sprayed or scrubbed, produces a surface that is very nearly the same as that of bush hammered granite. When the surface is cut with carborundum wheels a sort of terrazza effect is produced. Those who produce carborundum wheels use coarser aggregates than those who spray the surface or scrub it with acid or water. Whenever the same kind of aggregates are used, any one of these methods will produce a surface very similar to that produced by any of the other methods, excepting in the case of tamped stone. Tamped stone, when faced with white cement and granite, can be made wet enough to produce a surface that is practically the same as cast stone, but as a rule, manufacturers make it drier than is necessary, and the result is that the tamped stone is darker in appearance than cast stone. When both have to be used in the same building (as is frequently the case at Mooseheart), the tamped stone must be made just as wet as possible, in order that there may be no noticeable difference in appearance between that and the cast stone.

In our work at Mooseheart, where we produce our own blocks and trim stone, and also do our own construction work, we frequently cast arches over windows and door openings right in place at the building, facing the surface with granite and white cement to match the other stone. This requires considerable skill in order to make the two kinds of stone match perfectly. Usually we remove the surface forms within a few hours after the forms are filled, and spray the surface of the stone. The

next day we scrub it and about the third day we cut false joints in these arches to match up with the other blocks and trim stone. The false joints in these arches are filled with the same kind of mortar, as is used in the rest of the building. These are matched so well that many experienced men who have examined these buildings have been unable to see any difference in appearance between these arches cast in place and the adjoin ing blocks and trim stone. We use this method as a matter of economy, finding that the stone cast in place in this manner when there are several arches that are of the same size, can be produced at less cost than if the individual pieces were pre-cast in the cement plant and then set in place by the masons. From a manufacturer's standpoint, however, this would not be practicable, as the ordinary building mechanics are not competent enough to cast such arches in place to match stone that may be produced elsewhere. The largest arch we cast in this manner was 19 ft. inside diameter.

The manufacture of trimstone for high grade buildings always involves more or less the manufacture of high grade decorative stone. This is produced in glue or plaster molds—depending upon the nature of the ornaments. A plant producing such stone will require the services of modelers, model makers, and mold makers. Modelers receive the highest wages paid to men engaged in the concrete products business. Those who devote their entire time to this receive as much as $2.50 per hour. Some plants are fortunate enough to have modelers who also do plaster work when necessary, and occasionally such men can be had for $1.50 to $2.00 per hour, providing they are given all year around employment. Model makers receive from 90¢ to $1.25 per hour in union shops, and mold makers about 10¢ per hour less. In non-union plants the scale for model makers is about 85¢, and mold makers about 10¢ an hour less. We aim to produce mechanics who are good mold and model makers and can do ordinary modeling so they can work in any of these branches as needed.

Modeling.—A modeler will usually reproduce the desired ornament in clay or modeling wax. Occasionally he will carve it out of a block of plaster or use a combination of plaster and clay. When the model is completed by the modeler it is turned over to the mold maker, who produces a mold in which the original model can be re-produced in concrete.

Glue Molds.—If the piece is to be reproduced in a glue mold it must be shellaced thoroughly with orange shellac. The purpose of this is to keep the moisture in the clay from ruining the surface of the glue. If the model is to be reproduced in a plaster piece mold this treatment is not necessary. The next step in making a glue mold is to place a thin layer of clay over the entire model. The thickness of the clay should not exceed ¾ in.; this is later replaced with glue. The next step is to coat this with a thin layer of pure molding plaster of paris of the best grade obtainable. This must be worked so that the plaster does not harden before this section of the mold is completed. The next step is to build up the section with fiber dipped in plaster of paris. The fiber is used to reinforce the

plaster. Should the mold crack the fiber will hold the pieces together. It is the cheapest material obtainable for this purpose. Burlap can also be used, but is not as satisfactory. The fiber used can be purchased from leather tanneries and consists of the scrapings of hides, the surface of cocoanut shells and rope hemp. The plaster is mixed by partly filling a dish with water and then scattering a handful of plaster at a time over the entire surface of the water so it will absorb the water quickly and not form lumps. This should be continued until the plaster shows up at the surface of the water. It should then be stirred with the hand or a large spoon until it is of a creamy consistency.

Fig. 1 shows how shellac is applied to a clay model of a lion. Fig. 2 shows the building up of the clay partition. In this particular case straps

FIG. 1. (Left.)—APPLYING SHELLAC TO CLAY MODEL OF LION.
FIG. 2. (Right.)—BUILDING UP CLAY PARTITION.

of sheet metal were used for this purpose. When the section of the plaster jacket sets up, the plaster partition surrounding it is removed. The edges of the section are then trimmed off smooth, and joggle holes are cut into each edge. The edges are then shellaced and greased and the next section is built in the same manner. Fig. 3 illustrates the construction of the second section (which in this case is also the last section), of the mold for the lion.

The next step is to remove the plaster jacket from the model. When this is done the clay surrounding the model will usually adhere to the sections of the jacket. The surface of these plaster jackets is then scraped and trimmed as smooth as needed. They are then thoroughly shellaced and all the sections of the jacket and the model are then greased. The grease commonly used is made of kerosene and stearine wax mixed in the proportion of four parts of kerosene to one part of wax. The jacket is then reassembled around the model and clamped with clamps or fiber and

plaster ties across the joints. A funnel is then set over the top of the mold and held in place with a fiber and plaster tie. The mold is then poured full of hot glue. The glue used is known as "casting glue" or "Gelatine," and can be purchased of large packing companies, tanneries and wholesale paint houses. The glue comes in flake form, and is prepared for use as follows: The amount of glue required for the mold is placed in a tub or pail and covered with water. After about five minutes all the water is strained off as well as possible, through a gunny sack or screening. The glue is then placed in a steam or hot water jacketed kettle until it melts. It is then allowed to cool for about thirty minutes, after which it is poured into the mold. The mold is then allowed to stand over night to allow the glue to cool and harden. The following day the clamps or

FIG. 3. (Left.)—PUTTING TOGETHER MOLD SECTIONS.
FIG. 4. (Right.)—GLUE AND PLASTER JACKET.

plaster ties are removed and the jacket pried loose by driving an ordinary wood chisel into the joints of the mold. The glue jacket is then cut through to the model on the lines corresponding to the joints in the plaster jacket. The pieces of glue are then removed from the model and the model can be destroyed or set aside for further use.

Fig. 4 shows this glue and plaster jacket for the seated lion. The next step is to powder the surface of the glue with pulverized soapstone, commonly known as "French Chalk." This is rubbed into the surface with a dusting brush. The purpose of this is to remove all grease from the surface of the glue. The glue is then thoroughly painted with a saturated solution of powdered alum and water. This is done to harden the surface of the glue. The glue is then allowed to dry for two hours or so and is then painted with a paint of the consistency of cream, made up of litharge, linseed oil, turpentine and Japan drier, mixed in equal parts of each in-

gredient. This paint is then allowed to dry on the glue twelve hours, or over night, and will thoroughly waterproof the surface of the glue. Without this treatment only one or two good casts could be produced with a glue mold, whereas molds so treated can oftentimes be made to produce as many as ten or twelve casts. Some manufacturers use white lead paint, and heavy varnishes for the same purpose, but in our opinion, the litharge paint gives the best results.

After all this treatment the mold is ready for the production of concrete casts. The concrete should be mixed to a slushy consistency so it will run freely enough to get into all the details of the molds. It is best to make it as dry as possible, but the driest mix used usually is what would be termed at least "sloppy." In warm weather the mold can be removed from the product the following day, but in cold weather it is best to leave it in the mold for two days or longer. The product should then be steam cured for at least two more days, after which it can be surface treated. When the cast leaves the mold it usually has some defects, in which case it should be pointed up with the same mixtures as was used in the original cast. This can be done either before or after it has been steam cured. If done after it is steam cured, the product should be put back in the kiln for at least another 24 hours. The best way for surface treating the product is then to dip it in a solution of muriatic acid and water, as already described. The product has to remain in the acid solution from three minutes to an hour—depending on the age of the product, the effect that is desired, and the material that is used.

Plaster Molds.—Any piece produced in a glue mold can also be produced in a plaster piece mold; some manufacturers prefer the plaster piece molds to glue molds. This preference ofttimes is not based on good judgment, however, as I will bring out later. In producing a plaster piece mold the problem is somewhat similar to the manufacture of a glue mold. The first step, however, is to build a small section at a time that will draw freely from the model. This section should be made as large as possible, but if the model is highly ornamented it will usually be very small—sometimes just a few inches in each direction. A mold for a small ionic cap for a 12 in. column may consist of 30 to 35 pieces in all. A clay partition is built up in the same manner as for a glue mold, and a section made of plaster reinforced with fiber. When one section is completed the surrounding clay partition is removed and a similar partition built around the adjoining section. This section is produced in the same manner until the entire model is surrounded with small pieces of plaster, all of which will draw freely from the model.

The pieces of the mold are usually marked to indicate the order in which they should be removed from the cast and reassembled again in the mold. These pieces, when completed, are surrounded with a casing of plaster to hold them in their correct positions. The edges of each piece of the mold as it is made are shellaced, as described for the glue mold, and when the entire mold is completed all inside surfaces of the mold are

shellaced and greased as described before. The mold is then filled with concrete in the same manner that glue molds are poured.

Choice Between Glue and Plaster Piece Molds.—When only a few pieces are to be made from a given mold it is usually more economical to make a glue mold for the purpose, rather than a plaster piece mold. If a large number of pieces are to be made from the same mold it may be more economical to use the plaster mold instead. Many manufacturers, in my opinion, err in using plaster piece molds for almost all their work. We have found from actual experience that if a given piece is highly ornamented, a glue model can usually be produced for half the cost of a plaster piece mold. The further advantage of a glue mold over a plaster piece mold is that there are less joints in the mold, and consequently a lesser number of seams in the finished cast that have to be removed and pointed. This means that the actual manufacturing costs of the concrete cast is less in a glue mold than in a plaster mold.

In producing stone that must be true in all dimensions to the plans, great care must be taken that the lines of the mold are correct and that the glue does not become too soft, else the mold will bulge and the cast be out of shape.

Model Making.—If the piece that is to be reproduced is symmetrical in shape the model is usually made of plaster by a model maker. In large plants certain men make models only, others only make molds, and still others do only modeling.

The first step in producing a model is to make a sheet metal templet corresponding in shape to the reverse of the section to be produced. If the piece to be produced is a straight molding this templet is mounted on a board. It is necessary to have a flat top table, preferably covered with a piece of slate that has a true, straight edge, perfectly square with the top of the table. The templet mounted on a board is run along the edge of this table. Plaster and fiber are set on the table in front of the templet, and the templet is run in one direction over this, and scrapes the plaster to the shape of the templet. The molding gradually takes form, and the process is continued by adding more plaster to the form, as needed. After the molding is completed it is cut in pieces like lumber, with a saw, and mitered and fitted to the desired size. The sections are then stuck together with plaster of paris, and the joints pointed up neatly with plaster until the model is finished true to the design. It is then shellaced and greased in the same manner as a clay model.

The mold for reproducing this is usually made of plaster, but glue molds can be used if desired.

If the section to be produced is cylindrical in shape the templet is mounted on a stand slightly more than half the diameter above the top of the table. An axis consisting of an iron pipe is then set the proper distance from this templet at the same level as the templet. The center of this pipe forms the axis of the finished model. A handle is attached to one end of the pipe by means of two elbows and two short pieces of pipe. The

FIG. 5. (Upper Left.)—MOUNTED TEMPLET FOR STRAIGHT MOLDING. FIG. 6. (Upper Middle.)—FIRST OPERATION IN RUNNING MOLDING. FIG. 7. (Upper Right.)—MOLDING ALMOST COMPLETED. FIG. 8. (Lower Left.)—TEMPLET AND PIPE FOR BALUSTER. FIG. 9. (Lower Middle.)—BALUSTER BEING FORMED. FIG. 10. (Lower Right.)—FINISHED BALUSTER.

next step is to put a thin layer of clay on the pipe so that the model, when finished, can be removed readily from the pipe. Plaster of paris, mixed to the consistency of thick cream, is then poured on this axis. As it starts to set up the pipe is revolved slowly. The templet cuts off the surplus material and gradually forms the plaster to the shape of the templet. More plaster is added to the rough model, as needed, and this process is

FIG. 11. (Left.)—MAKING BALL.
FIG. 12. (Right.)—POURING LION.

continued until the model is completed. When the model is completed it is removed from the axis, and assembled with other parts to make the finished object.

Fig. 5 shows the mounted templet for a straight molding, Fig. 6 the first operation in running a molding, Fig. 7 the molding almost completed, Fig. 9 how a model for a ball is made. A pier cap is produced from the molding made in Fig. 7, and the ball made in Fig. 11. Fig. 9 shows a templet and pipe all ready to spin a baluster. Fig. 10 shows the baluster being formed.

QUALITY CONTROL IN CONCRETE PRODUCTS PLANTS.

By Stanton Walker.*

The present day concrete products manufacturer shows a marked interest in the quality of his product and means for controlling it. This is evidenced by the progressive spirit shown by local and national organizations of manufacturers. In the earlier days the manufacturer seemed to have the idea that concrete was any mixture of cement, aggregate and water, and that any kind of concrete was satisfactory for concrete products so long as it would "get by." They are now fully alive to the fact that intelligent control of the materials and proportions in concrete is essential to the maintenance of a uniformly high quality product, and will return dividends on the capital invested in such control.

The object of this paper is to point out the fundamental principles involved in concrete mixtures and their application to the work of the concrete products manufacturer. The principles described were developed at the Structural Materials Research Laboratory. The research work of this laboratory is being carried out through the cooperation of Lewis Institute and the Portland Cement Association, under the direction of Prof. Duff A. Abrams.

Fundamental Principles.

Uniformity of quality of concrete depends on the care with which the following variables are controlled:

- Cleanness of aggregate,
- Structural quality of particles of aggregate,
- Size and grading of aggregate,
- Quantity and quality of cement,
- Quantity of mixing water,
- Curing condition of concrete,
- Age of concrete,
- Manipulation of concrete (time of mixing, method of making, type of machine, etc.).

These factors may be said to give concrete its start in life, and if intelligently controlled will enable the concrete to give a good account of itself under the most adverse conditions.

The following discussion points out briefly the effect of these variables on the strength of concrete. A better understanding of the fundamental relations involved will enable the manufacturer to produce a more uniform and higher quality product. The data reported are, for the most part, from compression tests of 6 x 12-in. concrete cylinders. The concrete was hand-mixed in batches of sufficient size for one cylinder and was

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TABLE I.—EFFECT OF SIZE AND GRADING OF AGGREGATE.
(Data from Series 122)

Compression tests of 6 x 12-in. concrete cylinders.
Mix by volume.
Relative consistency 1.10. (Slump about 3 to 4 in.).
Cement: a mixture of 4 brands of portland cement purchased in Chicago.
Aggregate: sand and pebbles from Elgin, Ill.
Specimens stored in moist room until test; tested damp.
Each value is the average of 5 tests made on different days.

Size of Aggregate.		Fineness Modulus.	Fine Aggregate, Per Cent by Weight of Total Aggregate.	Compressive Strength, lb. per sq. in., for Different Mixtures.					
Fine.	Coarse.			1 : 9	1 : 6	1 : 5	1 : 4	1 : 3	1 : 2
EFFECT OF SIZE OF AGGREGATE.									
0 to No. 28	....	1.30	100	90	240	300	520	790	1710
0 to No. 14	....	2.20	100	120	390	510	750	1300	2670
0 to No. 8	....	2.70	100	150	500	680	970	2160	3270
0 to No. 4	....	3.00	100	180	590	1290	1330	2360	4130
0 to ⅜ in.	....	4.00	100	450	1080	1630	2270	3510	4160
0 to No. 4	No. 4 to ¾ in.	5.00	45*	710*	1680*	2230*	2700*	3800*	4220*
0 to No. 4	No. 4 to 1½ in.	5.65	34	1110	2040	2650	2990	4030	4250
EFFECT OF GRADING OF AGGREGATE.									
0 to No. 4	No. 4 to 1½ in.	3.00	100	180	590	1290	1330	2360	4130
		4.65	60	460	1190	1890	2430	3240	4550
		5.65	34	1110	2040	2650	2990	4030	4250
		6.00	25	960	1960	2370	3010	3920	4230
		6 30	17	700	1590	2180	2550	3650	4140
		6.65	9	570	1130	1670	2390	3080	3740

* Interpolated from curves.

TABLE II.—EFFECT OF QUANTITY OF MIXING WATER ON THE STRENGTH OF MACHINE-MADE CONCRETE BLOCK.

Compression tests of 8 x 8 x 16-in. hollow concrete building blocks.
Mix 1 : 5 by volume.
Age at test about 28 days.
Each value is the average of 10 tests; 5 from steam and air cured blocks and 5 from air cured blocks.

Consistency.	Water Ratio to Volume of Cement.	Compressive Strength.	
		lb. per sq. in. of Gross Area.	Per Cent of Wet Block.
Dry	0.59	860	80
Medium	0.70	1040	97
Wet	0.81	1070	100

March 22, 1923.

puddled into steel forms by means of a ⅝-in. round rod bullet shaped at the lower end. The tests were made on plastic concrete such as might be used for ordinary structural purposes or for "cast" block or pipe Although the cylinder tests do not duplicate the conditions for machine-made products, other tests made at our Laboratory on concrete building units and given in part below, indicate that the concrete for such products follows the same laws.

Cleanness and Quality of Aggregate.—Cleanness and structural quality of aggregate have been placed at the head of the list since this factor is of prime importance. Dirty and unsound aggregates may counterbalance the effect of attempts to improve the quality of concrete by changes in grading of aggregate, quantity of cement, etc. Aggregate may contain material harmful to the resulting concrete in the shape of aggregate particles which are not durable when exposed to the weather, such as shale, or as impurities of a nature which react with the cement, and retard or prevent its hardening. The colorimetric test affords a method for detecting organic impurities in aggregates. This test is described in "Abrams-Harder Field Test for Organic Impurities in Sand," *Proc.* Am. Soc. Testing Mat., Vol. XIV, Part 1, 1919. The method of making the test has been made a standard of the above Society (Serial Designation C 40-22). The necessary materials for making the test can be purchased at any drug store—a supply of a 3% solution of sodium hydroxide (NaOH) and a 12-oz. bottle. To make the test, fill the bottle to the 4-oz. mark with sand and to the 7-oz. mark with sodium hydroxide. Shake thoroughly and allow to stand over night. If the sand is suitable for high-grade concrete the liquid will remain clear or nearly so. A dark color, of the shade of strong tea or darker, indicates the presence of deleterious matter which will reduce the strength of the concrete. So far as we know the only material which commonly occurs in natural sands which will give a color in this test and at the same time have no material effect on the strength of concrete is lignite. This material is readily identified. Its presence in other than small quantities is undesirable, as it produces "blow holes" in the surface of the concrete which present an unsightly appearance.

The colorimetric test also serves to determine the silt content. The silt settles on top of the sand and the relative volumes of silt and sand can be estimated.

In the discussion of the effects of the other variables listed above, it is assumed that the aggregates are satisfactory so far as cleanness and quality of particles are concerned.

Size and Grading of Aggregate.—Table I shows the effect of size and grading of aggregate for different quantities of cement. In the first group of tests the size was varied from a fine sand all of which passed a 28-mesh sieve to a concrete aggregate well graded up to 1½ in. The second group shows the effect of varying the proportions of fine and coarse aggregate.

It will be noted that for the first group of tests the strength of concrete of a 1:5 mix made with 0-1½ in. aggregate was about 9 times that

obtained for the same mix with the finest sand. In the second group of tests decreasing the sand from 60% of the total aggregate to 34% increased the strength of 1:5 concrete 40%. These data show the vital importance of proper grading of aggregate and indicate that great economies can be effected in many instances by adding coarser sizes to the aggregates in use.

The maximum size of aggregate which can be used will be governed

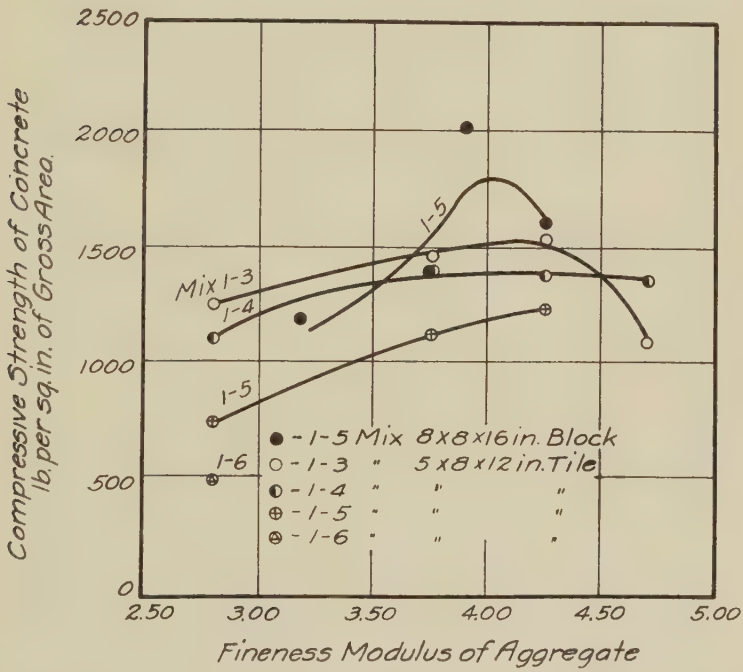

FIG. 1.—EFFECT OF GRADING ON THE COMPRESSIVE STRENGTH OF CONCRETE BUILDING UNITS.

Compression tests of commercial concrete block and structural tile. Units made under ordinary plant conditions.

by the dimensions of the product; the largest size of particle should not be greater than one-half the thickness of the minimum cross section.

The results of compression tests of 8 x 8 x 16-in. hollow concrete building block and 5 x 8 x 12-in. hollow structural tile made with different gradings of aggregate are shown in Fig. 1. The different gradings were obtained by mixing 0 to No. 4 sand and No. 4 to ⅜-in. pebbles in different proportions. The block and tile were made at concrete products plants under ordinary working conditions. The proportioning of the materials

was under the supervision of E. W. Dienhart, of the Portland Cement Association, and the writer. The compressive strengths are given in pounds per square inch of gross area. These tests show the same general relations as were found for the cylinder tests. They indicate that the laws of concrete mixtures for Laboratory conditions also hold for plant conditions.

In Table I and Fig. 1 the *fineness modulus* has been used as a meas-

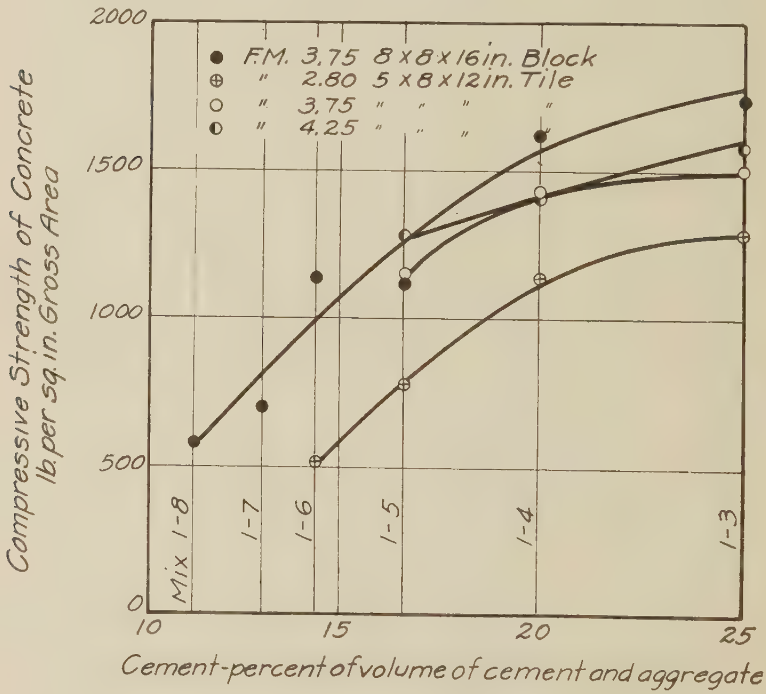

FIG. 2.—EFFECT OF QUANTITY OF CEMENT ON COMPRESSIVE STRENGTH OF CONCRETE BUILDING UNITS.

Compression tests of commercial concrete block and structural tile. Units made under ordinary plant conditions.

ure of the grading of the aggregate. The fineness modulus is a "yard stick" by which the effectiveness of the grading of an aggregate may be measured; the calculations necessary for its application are discussed in more detail below.

Quantity of Cement.—Table I also shows the effect of variation in the cement content. For example, a 1 : 3 mix of 0-⅜ in. aggregate is 225% stronger than a 1 : 6 mix. These data as well as many others show that for the usual range of mixtures the compressive strength of concrete is increased about 1% for each additional 1% of cement.

Fig. 2 shows the effect of quantity of cement on the compressive strength of commercial concrete block and structural tile. The data for the tile are also shown in Fig. 1. A relation similar to that shown by tests of concrete cylinders was found for the building unit tests.

Quality of Cement.—The quality of the cement affects the strength of

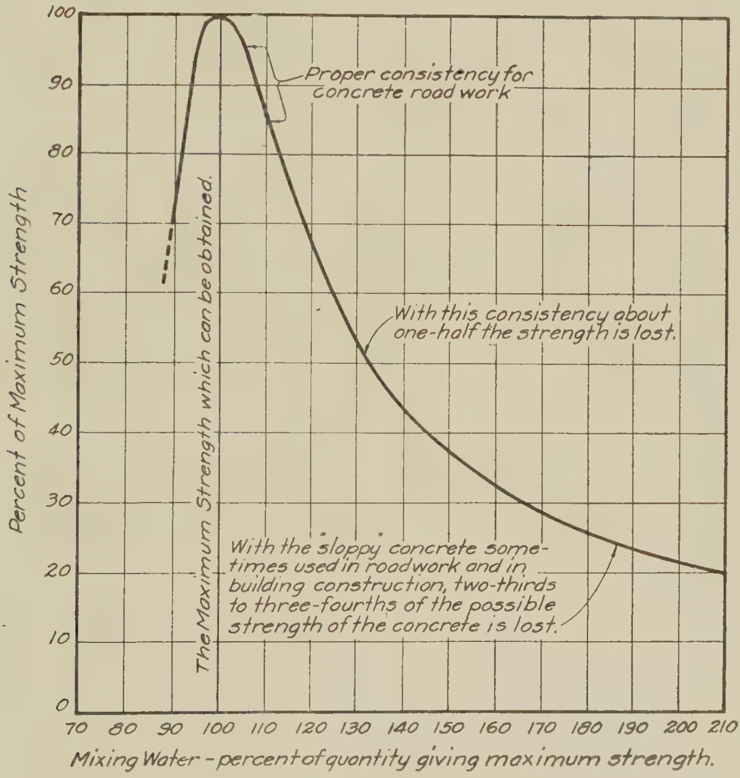

FIG. 3.—EFFECT OF QUANTITY OF MIXING WATER ON THE STRENGTH OF CONCRETE.

Based on compression tests of 6 x 12-in. concrete cylinders.

the resulting concrete. However, cement is manufactured to conform to certain minimum requirements, and any variation in quality must be above this minimum. Changes in quality of the resulting concrete due to variation in cement are small when compared with the variations due to other causes.

Quantity of Mixing Water.—The quantity of mixing water is of utmost importance in fixing the quality of concrete, whether the concrete be the dry mixture used for machine-made products or the plastic mix-

ture used for "cast" products and ordinary structural purposes. It has been shown by many tests that so long as the concrete is workable the ratio of volume of water to volume of cement fixes the strength regardless of the quantity of cement, plasticity of concrete, or grading of aggregate. For example, a rich mixture is stronger than a lean one because it can be mixed to a given plasticity with a smaller quantity of water expressed in terms of the cement.

Fig. 3 shows the variation in strength of concrete for average conditions with different quantities of mixing water. The strength is expressed as a percentage of the maximum strength attainable and the water as a percentage of the amount required for maximum strength, with a given method of manipulation. The quantity of water represented as 100% should not be confused with the term "relative consistency 1.00" or "normal consistency," frequently used in our publications. These terms refer to the *plastic condition* of the concrete, while in Fig. 3 100% represents the amount of water which will give maximum strength; the exact quantity of water required depends on several factors—grading of aggregate, proportions, etc., and of prime importance among them is the method employed in placing the concrete. For a given condition, the maximum strength will be obtained with less water for concrete vigorously tamped, jigged or pressed into the form than for concrete poured into place without tamping, etc. That method which will allow one *properly* to place the concrete with the least water will give the *highest strength* obtainable for a given quantity of cement, grading of aggregate, curing condition, etc. One of the things that must be guarded against in the manufacture of machine-made products is the use of *too little* water to permit placing the concrete in a dense, compact mass.

Table II gives data of compression tests of machine-made concrete blocks for three consistencies: "dry," "medium" and "wet." The "dry" consistency represents the use of about the smallest amount of water and the "wet" consistency the greatest amount which permitted the forms to be stripped immediately. For the "medium" consistency, the amount of water was the average of the two extremes. The dry block gave a strength of only about 80% of that obtained for the wet consistency.

Quality of Mixing Water.—Recent tests of impure waters for mixing concrete show that the quality of the mixing water can be varied over a wide range without affecting the strength of the concrete. Tests of concrete were made using about 65 different samples of mixing water which included fresh waters, bog waters, sea and alkali waters, solutions of common salt, mine and mineral waters, and waters contaminated with sewage and industrial waste. The most striking feature of the investigation is that most of the water samples gave good results in concrete. Exceptions to the foregoing statement are acid waters, refuse from tannery, refuse from oil refinery, and waters containing more than about 10% common salt.

Effect of Curing of Concrete.—Fig. 4 A, 4 B and 4 D show the important influence of the condition of curing on the strength of concrete.

Fig. 4 D gives data of compression tests of 6 x 12-in. concrete cylinders at the age of 4 mo. when stored in air until test and in damp sand at

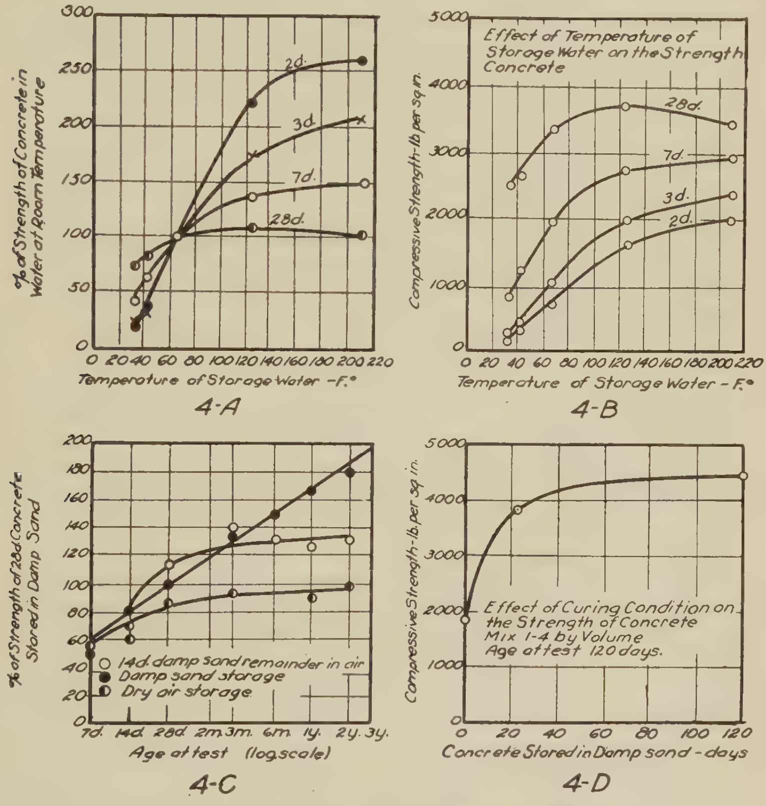

FIG. 4.—TYPICAL CONCRETE STRENGTH RELATIONS.

Compression tests of 6 by 12-in. cylinders. Mixed by volume. Sand and pebble aggregate. In general each value is the average of five or more tests made on different days.

various periods up to the time of test. Concrete kept moist for 20 days had about 75% more strength than that stored in air the entire time until tested.

Fig. 4 A and B show the effect of storing concrete in water at various temperatures, ranging from ice water to boiling water. While these tests do not duplicate the conditions in a steam curing room, they show the effect of *temperature* when other conditions are constant. The strength of

concrete increased rapidly with the temperature of the storage water for the early ages, say 2 or 3 days, and a relatively small amount at 28 days. At 2 days the strength of concrete stored in water at about 110° F. was double that obtained for a temperature of 65° to 70° F. Concrete 3 days old cured at 110° F. gave about the same strength as that 7 days old cured at 70° F.

In these tests, both *moisture* and *heat* were present. For steam-cured products nothing will be gained by raising the temperature of the steam room unless the room is also kept moist; in fact, harm may be done by drying out the concrete and as noted below, arresting the increase in strength.

Age of Concrete.—So long as concrete is kept moist it continues to increase in strength with age. If it is allowed to dry out the chemical action of the cement is arrested and no further gain in strength takes place. Certain tests made at other laboratories indicate that if concrete is stored in a moist place after having been allowed to dry out it will again gain in strength.*

Fig. 4 C shows the effect of ages up to 3 years on the strength of concrete for three different curing conditions; (1) concrete kept moist until test, (2) concrete kept moist 14 days and then cured in air of laboratory until test, and (3) concrete cured in air of laboratory from the time of removal from molds.

The age at test is platted to a logarithmic scale. The strength of the concrete cured in a moist place is a linear function of the logarithm of the age.

Manipulation of Concrete.—The thoroughness with which concrete is mixed and the energy expended in placing it in the forms exert an important influence on the strength of the concrete. Tests carried out at this Laboratory on concrete machine-mixed for periods ranging from 15 seconds to 10 minutes show that the strength increases with the mixing time.* For the conditions of these tests the strength increased rapidly up to about 1½ to 2 minutes. Beyond this time the gain in strength was comparatively little. The most efficient mixing time will undoubtedly vary somewhat with the type of mixer.

Fineness Modulus of Aggregate.—The fineness modulus was mentioned above as a measure of the grading of the aggregate.** This function is the sum of the percentages in the sieve analysis divided by 100, when the sieve analyses are expressed as cumulative percentages coarser than each of the following sieves: 100, 50, 30, 16, 8, 4, ⅜-in., ¾, 1½, etc. An important characteristic of these sieves is that the clear opening of each

*Some tests on the effect of age and condition of storage on the compressive strength of concrete, by H. F. Gonnerman. Proc. Am. Conc. Inst., v. XIV, 1918.

*See "Effect of Time of Mixing on the Strength and Wear of Concrete" by Duff A. Abrams, Proc. Am. Concrete Inst., 1918.

**For a detailed discussion of the effect of grading of aggregates see Bulletin 1 of the Structural Materials Research Laboratory, Lewis Institute, Chicago, "Design of Concrete Mixtures," by D. A. Abrams.

is double that of the next smaller. These are the sieves recommended in the "Tentative Method of Test for Making Sieve Analysis of Aggregate for Concrete" (Serial Designation C 41-21 T), of the American Society for Testing Materials.

Table I and Fig. 1 show that the strength of concrete increases as the fineness modulus increases, or as the aggregate becomes coarser, so long as the concrete is workable. The second group of tests in the table

TABLE III.—MAXIMUM PERMISSIBLE VALUES OF FINENESS MODULUS OF AGGREGATE.

Data from Table 3, Bulletin 1, Structural Materials Research Laboratory, "Design of Concrete Mixtures." Based on requirements for sand and pebble aggregate, composed of approximately spherical particles.

Mix by Volume.	Size of Aggregate.				
	0 to No. 8.	0 to No. 4.	0 to ⅜ in.	0 to ½ in.	0 to ¾ in.
1 : 7	2.55	3.20	3.95	4.35	4.75
1 : 6	2.65	3.30	4.05	4.45	4.85
1 : 5	2.75	3.45	4.20	4.60	5.00
1 : 4	2.90	3.60	4.40	4.80	5.20
1 : 3	3.10	3.90	4.70	5.10	5.50

TABLE IV.—TYPICAL SIEVE ANALYSES OF SAND AND PEBBLES.

These sieves are recommended for sieve analyses of aggregate in the "Tentative Method of Test for Sieve Analysis of Aggregates for Concrete" of the American Society for Testing Materials.

Sieve No.	Size of Square Opening, in.	Per Cent by Weight Coarses than Each Sieve.		
		Fine Sand.	Well-Graded Sand.	Pea Gravel.
100	0.0058	82	97	100
50	0.0116	52	81	100
30	0.023	20	63	100
16	0.046	0	44	100
8	0.093	0	25	95
4	0.185	0	5	60
⅜ in.	0.375	0	0	0
Fineness Modulus*	....	1.54	3.15	5.55

* Sum of the percentages in the Sieve Analysis, divided by 100.

shows that beyond a fineness modulus of about 5.65 to 6.00 for aggregate graded up to 1½ in. the strength decreases. Beyond this point the aggregate is too coarse to give a workable concrete for the quantity of cement used. The maximum permissible fineness modulus depends on the quantity of cement, the maximum size of aggregate, the type of aggregate, and method of placing the concrete. Table III gives maximum permissible values of fineness modulus for different mixtures and sizes of aggregate. These limiting values were determined from strength tests of 6 x 12-in. cylinders. Some departure from them may be necessary for different

methods of manufacture. In general, however, they will be found to agree fairly well with the requirements of concrete products.

Table IV gives sieve analyses of typical aggregates. The higher values of fineness modulus represent the coarser aggregates. It will be seen at once that the same fineness modulus can be arrived at for a wide range in sieve analyses. However, so long as the concrete is workable the fineness modulus of the aggregate measures its effect on the strength of the concrete.

The following examples illustrate the simple calculations necessary, to use the fineness modulus in determining proportions of aggregate.

(1) Assume two aggregates available, a sand having a fineness modulus of 3.00 and pebbles having a fineness modulus of 5.00. It is desired to mix them together in the proper proportions to give a fineness modulus of 4.00.

Subtract the fineness modulus desired from the fineness modulus of the coarse aggregate and divide this by the difference between the fineness moduli of the coarse and fine aggregates. This will give the proportion of fine aggregate in terms of the separated volumes of fine and coarse aggregate.

For the above example, this becomes

$\frac{5.00 - 4.00}{5.00 - 3.00} = \frac{1.00}{2.00} = 0.5$; or 0.5 volumes of fine aggregates to 1 volume of fine and coarse measured separately.

(2) For the two aggregates in the first example determine the fineness modulus of a mixture made up of 3 volumes of sand to 2 volumes of coarse aggregate.

Multiply the fineness modulus of the fine aggregate by the number of volumes of fine aggregate; to this add the product of the fineness modulus of the coarse aggregate by the number of volumes of coarse aggregate; divide this result by the sum of the volumes of fine and coarse measured separately, as follows:

$\frac{(3 \times 3.00) + (2.0 \times 5.00)}{5} = \frac{19}{5} = 3.8$, the fineness modulus of a mixture of 3 volumes of sand and 2 volumes of the coarse aggregate.

CLOSURE.

The above discussion points out briefly the influence of the more important variables on the compressive strength of the concrete. Other methods of testing concrete, as well as experience gained from observation show beyond doubt that the same variables which influence compressive strength affect other desirable qualities of concrete in a similar manner.

The bearing these relations have on making uniformly higher grade and more economical products is obvious. Their application is a problem for each manufacturer. The following summary emphasizes some of the more important relations:

(1) Aggregates must be free from organic impurities and made up of durable particles.

(2) So long as the concrete is workable the strength is greater for coarser aggregates. The coarser the aggregate the higher the fineness modulus. The fineness modulus furnishes a ready means of grading aggregate economically.

(3) For the usual mixtures the addition of 1% of cement increases the strength about 1%.

(4) The quantity of mixing water which will produce maximum strength is the least amount which will allow the concrete to be placed properly and depends on the manipulation of the concrete. Use as near this quantity of water as conditions of manufacture will permit.

(5) Moisture is essential to the proper curing of concrete. High temperature coupled with moisture hastens the hardening process. Concrete continues to increase in strength so long as it is kept moist.

(6) Thorough mixing is essential to good concrete.

An Analysis of the Variables in Concrete From the Construction Standpoint.

By Walter P. Bloecher.*

The Question of Uniformity.—With our present-day refinement in the design and application of concrete, the principal problem of the industry, stated in the abstract, is how to get predetermined uniformity of strength. Recent researches have perfected our knowledge of the factors involved to such an extent that, given normal materials and conditions, this can be accomplished in any good laboratory with reasonable certainty of results.

Results obtained from field tests have, on the other hand, quite commonly been irregular and inconsistent. Indeed, they have varied so widely and unexplainably as to cause much concern to the construction managements; and it is a fact that this concern has often been replaced by indifference as the apparently overloaded structures still stood up.

The problem of getting uniform results in the field is distinctly different from that in the laboratory. In the latter generally all of the many variables are and can be rigidly controlled, except the particular ones under investigation. This control is possible to a degree unattainable in practice by (1) use of selected uniform materials (often artificially prepared) of known characteristics; (2) methods and apparatus of great precision; (3) protection from weather; (4) absence of the necessity for strict economy; (5) skilled permanent talent, and (6) the relatively small magnitude of the physical operations. These, with all the sub-headings which they embrace, make up the wide gap between laboratory and field concrete.

The speaker recalls a recent construction operation with which he was connected on which erratic concrete test results were given a great deal of study. The testing laboratory, the cement, the organic sand impurities, the mica in the sand, insufficient mixing time, too much water, and improper curing of cylinders were sucessively blamed and studied. Finally a new laboratory was engaged, the sand was re-washed at added cost, the mixing and curing methods were made more strict, and somewhat better test results were had. But it is worth noting that no one could definitely place the credit for the improvement.

The Variables in Concrete.—The every-day construction man, on whom ultimately we must rely for better concrete, is generally not fully informed on the number and range of the factors that determine the quality of his

*With Stone & Webster, Inc.. New York City.

product. The large amount of valuable research work is scattered, complicated and difficult for him to study and apply in his busy life. He still reasons that an extra bag of cement per yard will more than counteract the fineness of his sand, the wet mix and the low temperature, without having any definite idea of the relative values of these factors. Table I has been prepared with the idea of giving him in brief tabular form a bird's-eye view of this research work to aid in solving such problems; or, re-stated, to provide condensed informatión on the variable conditions which may be affecting his product, with the degree of their possible influence.

It is not averred that the data are bullet-proof or complete; the problem is too wide and complex to permit of a simple presentation. It should be remembered also that different researches of the same variable have not always agreed; indeed they have sometimes given entirely contradictory results. Again, the values given represent the laws derived from testing small laboratory specimens, and in some cases the effect of the same variable on structural or mass concrete may be somewhat different. The information, accordingly, is useful more as indicating general trends than specific values. When so used it should be of some assistance to a construction man having concrete troubles and not knowing where to look.

It will be noted that twenty-seven factors are listed, together with the range of their individual influence on the strength of typical 1:2:4 building concrete, between the best and the worst conditions that may be encountered in practice. The physical conditions producing the high and low strength are given in each case; and the research authorities are appended for ease of quick further reference.

It is of course obvious that many of these separate factors are in a practical way interdependent. Thus, in studying the gradation of aggregates, this may be taken up from the standpoint of the sand alone, the gravel alone, or the mixed aggregate; and in either case would involve, as noted in the remarks, a change in water ratio to maintain the same consistency. It is important to recognize that each factor is set out by itself, and the effect it has on the strength is given from the standpoint of a pure variable.

In attempting to evaluate or reduce the various factors to a common basis, it is only possible to express them in terms of the *percentage effect* they have on an approximate 1:2:4 mix. The research data, while in themselves pure, were secured by scattered agencies under such different conditions that it is impossible to co-relate the results in any other way. In some cases the results had to be given for other than 28-day 1:2:4 concrete, but the conditions are noted in all cases. This will explain why the highest strength at times appears as 3390 lb., and at others only 1500 lb. The normal limits of maximum variation were chosen with care, and

have in most cases some experience as a basis. In other cases, such as the water used in the mix, the limits of 3 in. and 10 in. slumps were arbitrarily selected as representing a reasonable practical range.

This table brings out several things of interest to the construction man. It shows, for example, that there are three factors which may be

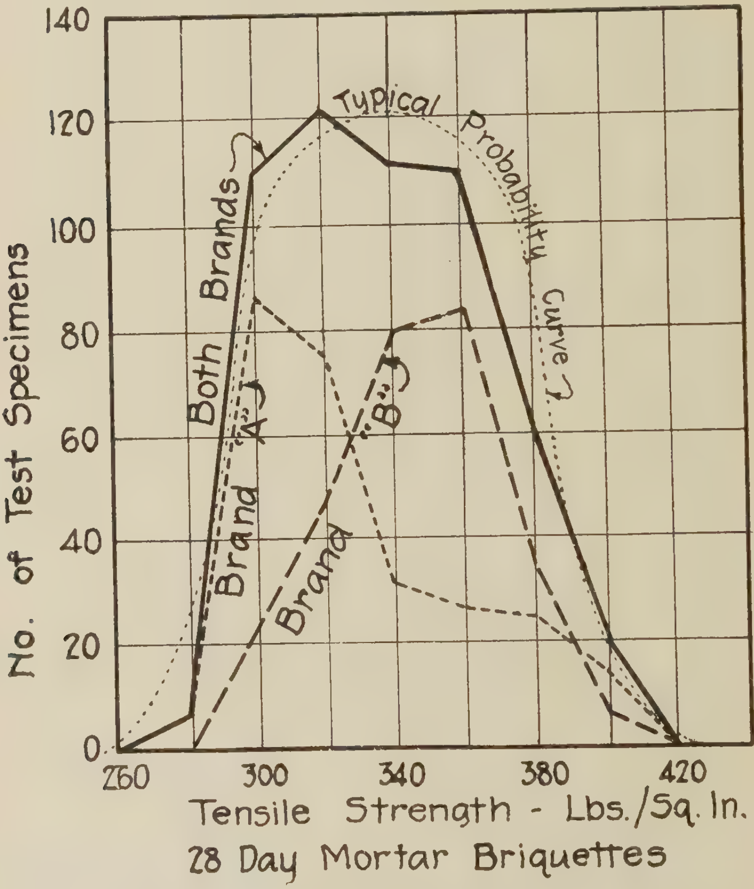

FIG. 1.—RESULTS OF 540 COMMERCIAL CEMENT TESTS OF TWO DIFFERENT BRANDS.
(From a recent Stone & Webster operation.)

of greater influence than the water-cement ratio under particularly poor conditions, viz., the cement variation, the organic content of the sand, and the method of curing. It also indicates the danger from such factors as storing cement, from mica in the sand, and from curing at cold temperatures.

STATEMENT SHOWING PRINCIPLE VARIABLE CONDITIONS AFFECTING TH
(INFORMATION SELECTED FROM LATEST PUBLISHED TEST RESULTS TO MOST CLOSE

MATERIAL OR OPERATION	NO.	VARIABLE	MAXIMUM RESULTING VARIATION IN STRENGTH FOR NORMAL PRACTICAL CONDITIONS					AUTHO VA
			HIGHEST STRENGTH		LOWEST STRENGTH		% RANGE = SPREAD / HIGH	
			CONDITIONS	LBS/SQ.IN.	CONDITIONS	LBS./SQ.IN.		
1		2	3	4	5	6	7 = (4-6)/4	
Cement	1-a	Variations as between brands	Strongest brand	4120	Weakest brand	1700	59	Lewis Instit of 22 Brar
	1-b	Chronological Variation in Individual brand	Standard Briquette	440	Standard Briquette	300	32	Stone & Webst large operat
	1-c	Fineness of Cement	8% retained on #200 sieve	3700	22% retained on #200 Sieve	2800	24	Bulletin #4. Lev 28 da. tests.
	2	Age when used - (storage effect)	No storage	100%	6 months old	68%	32	Bulletin #6. Lev 28 day cylin
	3	Quantity used - richness of mix	7 Bags / cu. yd = 1:1¾:3½ mix	3390	6 Bags / cu. yd. = 1:2:4 mix.	3010	11	Bulletin #4. Lew Cement F-4.
Sand	4	Fineness modulus - (grading)	Coarse sand F. M. 3.10	3200	Fine sand F. M. = 1.50	2650	17	Bulletin #1, Lew 1:5 mix.
	5	Quantity used - (accuracy of measure)	Undersanded 9 6 c.f / cu. ud.	3360	Oversanded 13 6 c.f. / cu. yd.	2710	19	Bulletin #1, Lew " 4, "
	6	Organic content - (loam)	No organic content	1500	0.20% Tannic acid by wt of aggregate	800	47	Bulletin #7, Lew Tannic acid or
	7	Clay (pure silt) content	10% silt		No silt			F. L. Roman, E
	8	Mica & Mineral content	No mica	100%	5% mica by weight of sand	70%	30	W.N. Willis, Engi
	9	Water content of sand	2% by weight = 3 gal. / yd batch - Rel con 1.15	2500	6% by weight = 9 gal. / yd batch - Rel con. 1.29	1900	24	Bulletin #4, Lev 1:5 mix.
	10	Round vs Sharp grains	Sharp grains	100%	Round grains	100%	0	U.S. Bureau Stand
Coarse Aggregate	11	Quality of stone - (hardness)	33,000# Trap	100%	4,400# soft limestone	100%	0	F. E. Giesecke, E in Engr-News-R
	12	Fineness modulus (grading)	Coarse gravel F.M. 7.4	3200	Fine gravel F. M. = 6.4	2600	19	Bulletin #1 Lew 1:5 mix.
	13	Quantity used - (accuracy of measure)	Too little gravel 20.0 c.f. per yd.	3200	Too much gravel 27.0 c.f. per yd	2700	16	
	14	Kind - Gravel - Limestone Trap & Granite	Granite	3300	Gravel	2250	32	U. S. Bureau St 58-1916 8&1
	15	Impurities - Organic & Clay	(See Sand Impurities)					
	16	Shape of Particles - Flat, Round etc.	Round, max = F.M. 5.4	2950	Flat, max F.M. = 5.15	2600	12	Bulletin #1, Lewis
	17	Size of Largest Particle	0 to 1½"	2320	0 to ¾"	2000	14	Abrams "Streng 1918 Am Con
	18	Use of Slag Aggregate	Slag and Bank sand	117%	Pebbles and Bank sand.	100%	17	Myers, Engr. Ne p. 956
Mixed Aggregate	19	Fineness modulus	F. M. = 5.95	3350	F. M. = 4.76	2200	34	Bullentin #1, Lew 1:5 mix.
Water	20	Quantity used per Batch	3" Slump (Rel Consistency - 1.05)	*2900	10" Slump (Rel. Consistency - 1.30)	1800	38	Bulletin #4, Lew 1:5 mix. Also.
	21	Temperature of Mixing Water	100° C	2800	0° C	2800		Abrams "Stren in 1918 Proc Am
Mixing	22	Length of Mixing Time	2 min.	3100	½ min	2800	10	Abrams, Am Co Fig 23. p49
Curing	23	Temperature at which cured	91° F	1530	35° F.	990	35	Bulletin #81. U. of Figs 8 & 10. p
	24	Artificial Heating - Protection	35° F.	990	26.5° F.	680	31	Bulletin #81. U. of and Table 16.
	25-a	Moist vs Air Cured	Damp Sand Storage	3800	Air Storage	2000	47	Bulletin #2. Lewi Pebbles. Rel. C
	25-b	Moist vs Air Cured	Damp Sand	5174	Air Storage	2774	46	Gonnerman on of Concrete. A
The 28 day Test Cylinder	26	Wet or Dry when Broken	Dried 4 days before breaking.	125%	Broken Moist	100%	25%	Greene. Trans. A
The Yard Stick Variable	27	Drilled vs Molded Cylinders	Drilled	2670	Molded	2480	7	R. E. Goodwin, N.Y Engr. News 2/ State Highwa

I

F CONCRETE, AND THE NORMAL MAXIMUM RANGE OF TEIR INFLUENCE
NAL 1:2:4 CONCRETE AT 28 DAYS SUCH AS IS SPOUTEDN BUILDING CONSTRUCTION)

	REMARKS
	9
ts	1·2·4 Cylinders· at 28 da. Spread at 6 mos. = 40%
	2 separate brands gave about same spread over a period of about 18 mos.
33·34	Fine grinding hastens early setting, also maintains greater strength with a.
ds	For 1 year old concrete (of cement stored 6 mos.) loss is only 24%, that is, there i recovery with age. Storage conditions make little difference.
	One added bag per batch, raising cement ratio from .18 to .202 has but little influe in strengthening concrete. Bullentin 8. p.62 for 10% hydrated lime indicates an increase of about 18 by one extra bag.
	A sand of varying fineness modulus is assumed combined with a gravel of consnt modulus = 7.0. Combined mix F.M.= High, 5.69; Low, 5.16. Higher modulus requires less water for same consistency, hence strofer cement paste.
5 mix	A sand of 2.4 fineness modulus is combined with a gravel of 7.0 fineness modus. Varying sand quantity produces combined mix F.M.·High = 5.69, Low = 5.34 giving 3200#, 2850# Cement factor is taken as 1% per 1% change in volume 5% added to undersanded, and 5% deducted from oversanded mix.
e	Results given are for 1:5 mix, composite average of 6 sizes - 5 ages - Fig. 4, 5 & 6.
	Small amounts of clean clay increase strength, but much depends on finens and distribution. Clay must be free from organic matter.
45.	Tests covered 1:3 motar briquettes. Ottawa sand gave 40% and Pittsburgquartz gave 27% loss for same Mica content.
4.	The effect on consistency of 6 additional gallons of entrained water, assung a desired consistency of 1.15, is to raise this to 1.29, with loss of strength shown
p.86	
s	These tests gave concrete of 1:1½:3 mix a strength of 6000# from stone wh tested only 4400.#
	A gravel of varying fineness modulus is assumed combined with a sand of modulus 2.3, constant. F.M. of mix = High, 5.70, Low 5.10 - See #5
	A sand of 2.4 modulus is combined with a gravel of 7.0 modulus. Assuming sand quantity constant at 11.6 c.f. per yd., varying gravel quantity changes combined F.M. from 5.62 to 5.31. Cement Facto as in 6
er	These results do not hold as a general law, they represent the lowest values otained by testing numerous kinds of each material. Results varied widely, some gravels testing stronger than granites.
.	This represents the "workability factor" as influenced by shape.
	1:5 mix used, 28 day specimens, 1 minute mixing time, water ratio 0.81, Table 1, Ref. 16 & 82.
)	P.J. Freeman Am. Conc. Institute 1918 Proc p 99 shows 10 slag samples were about 20% stronger than 5 granite, limestone and gravel samples at 30 da.
	Fine mix made up of sand F.M.=1.50, Gravel F.M.= 6.4, Combined F.M.= 4.7 Coarse " " " " " 3.10 " " 7.4 " " 5.9
	See also Bulletin #1, Lewis Inst. Table 5, p.16.
te"	Grand average of 120 cylinders 1:4 mix tested at 3 ages, 3 consistencies, showed radiation quickly warmed or cooled water to temperature of air. When combined with other factors this may become practically important.
	The spread is slightly greater at 28 da than 3 mos Table 12 p 80 also shows added mixing benifits finer aggregate more than coarse; Tests by Scofield in Engr. & Contr 1/17/15 show a variation in strength of about 12% from ½ to 2 min. Hatt, Am Conc Inst. 1921 shows consistency also increases with increased mixing. This does not take into account the mixing equivalent of spouting and placing.
0.	This shows the retardation in strength at 28 days by cold curing above freezing.
	It is assumed in freezing weather the concrete can be artificially heated to 35°F. If heated to 48°F strength increases 40% above that at 35°F.
	Bulletin 8, p.21 Table IX, indicates that at age 28 days the damp cured specimen is only 13% stronger, but it gains with age as indicated.
	These results are at age of 5 years and check 4 mos. tests of Abrams very closely. Gonnerman got spread of only 15% at 28 da. indicating air cured concrete quickly gets its max. strength; moist cured keep on gaining strength.
	Result is average of 4 series of tests
	This data is not conclusive. Pennsylvania State Highway results check this, while others show different results.

TABLE II.—SECONDARY AND INTANGIBLE VARIABLES AFFECTING STRENGTH OF CONCRETE.

Item.	Variable.	Remarks.
Sand	1. Use of Quarry Screenings	Fine quarry screenings generally bad, coarser screenings good.
Coarse Aggregate	2. Imperfect Screening—Presence of Small Size Particles	Supposedly screened gravel often contains 10–15 per cent aggregate finer than ¼ in. and may affect fineness modulus.
Water	3. Inpurities and Admixtures (See Pulver and Johnson, "Wisconsin Engineer," Oct., 1913)	No data on impurities. For salt (NaCl) each 1 per cent by weight of water reduces strength of 2 mo. concrete 2½ per cent, except for freezing conditions where its effect in lowering freezing temperature overbalances its bad chemical effect. Adding up to 12 per cent of NaCl increased strength from 450 to 1150 lb. For $CaCl_2$, adding up to 4 per cent by weight increased strength 17 per cent, then dropping off to same strength for 8 per cent.
	4. Leakage and Evaporation of Excess Water	No data.
	5. Absorption of Aggregates	This covers moisture actually absorbed as opposed to entrained moisture. No data.
	6. Normal Consistency of Cement as Affecting Water Requirement	No data.
Mixing	7. Kind and Condition of Mixer	This refers to mixer characteristics, worn blades, etc.
	8. Effect of Tamping, Spading, Hoeing, Hammering	Tamping with pointed bar seems better than tamping flat. Excessive vibration harms wet mixes, but improves dry mixes. See Lewis Institute Bulletin 3, Table 2, p. 7, and Table 4, p. 9.
	9. Effect of Spouting, Buggying, etc.	Unpublished tests indicate considerable remixing value in spouting.
Placing	10. Segregation of Aggregates	No data on its effect; important to avoid.
	11. Re-gaging after Initial Set	L. P. Sabin, "Cement and Concrete," p. 253, shows re-gaging without additional water slightly harmful. With water added to restore consistency, gave no loss; in fact, a slight gain.
Curing	12. Humidity and Wind	No data.
	13. Increase in Strength with Age of Concrete Weak at 28 days	No definite data. Results indicate that concrete weak by 28-day cylinders often gains more strength with age than the higher 28-day product.
	14. Pressure applied during Curing	Bulletin 3, Lewis Institute, p. 19, Fig. 13, shows 15 per cent increase in strength for 100 lb. pressure: 20–35 per cent for 200 lb.
	15. Effect of Wood vs. Steel Forms	No data. Wood forms may take away more surplus water than steel.
	16. Use of Manure for Protection	Chemicals may have bad effect on concrete.
Miscellaneous	17. The Human Equation	

In addition to the twenty-seven factors listed in Table I, it is well to mention numerous others having an influence on the strength of the final product on which the research data are either meagre or which are scarcely susceptible of analysis. Seventeen such factors of varying importance are briefly noted in Table II, with whatever information is available.

It is, of course, manifest that all, or even most of these factors do not occur simultaneously nor to the same degree on any individual job, or at any particular time. Each job has its own peculiar setup, which in turn is subject to variation within itself from day to day or even from batch to batch. The limitless combinations possible make the erratic test results quite understandable; they have suggested to the speaker the analysis of these results from the standpoint of the theory of probability.

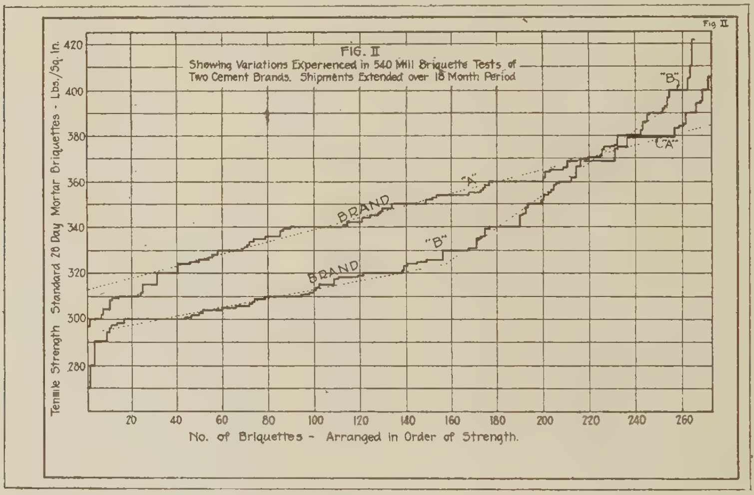

FIG. 2.—VARIATIONS IN 540 MILL BRIQUETTE TESTS OF TWO CEMENT BRANDS.
(Shipments extended over 18 months.)

Some Results of Job Testing.—Taking up first the cement factor, Fig. 1 shows the results obtained at the mill from 540 standard 28-day mortar briquette tests divided between two separate brands. They were picked at random from an order covering 100,000 bbl. of cement for a recent Stone & Webster operation; and their manufacture and shipment ran over a period of about eighteen months. The great similarity of this diagram to the probability curve will be instantly noted. It may be argued that there is no direct relation between tensile tests or mortar and compressive strength of concrete. This may or may not be strictly true; still these briquette results will surely indicate the general effect on uniformity which can be expected from the cement factor.

Fig. 2 represents this same data plotted in different form. In this

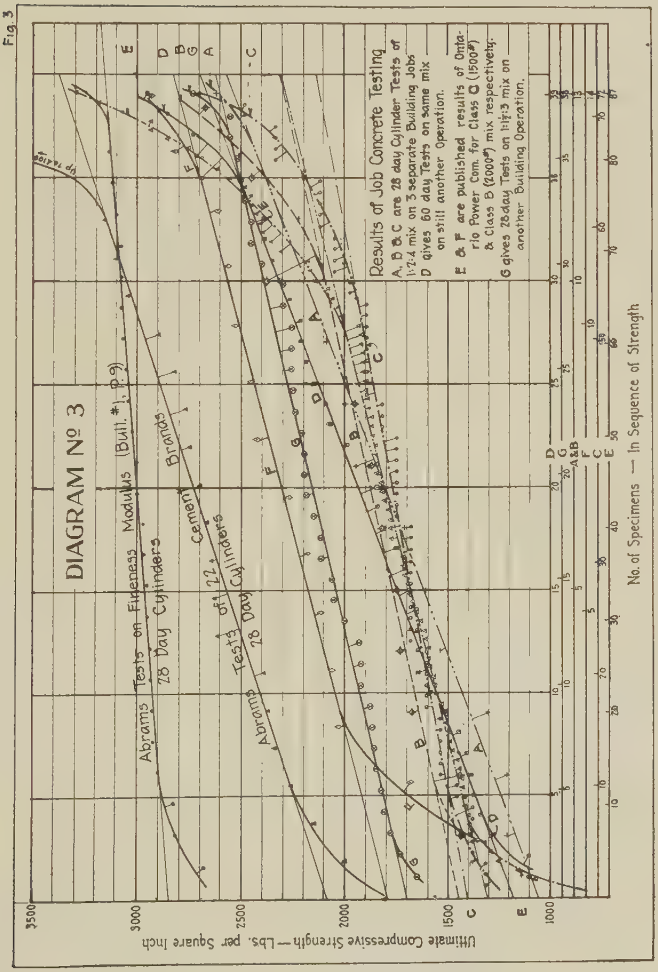

FIG. 3.—RESULTS OF JOB CONCRETE TESTING.

case the individual results are arranged horizontally in the order of their strength, and are plotted to produce a curve which may be called a Progressive Strength curve. This progressive strength curve simply takes the sequence of strength as the index or order of plotting, to roughly produce a smooth graph. A probability curve expanded to this basis will always take such a general shape. It is obvious that the general measure of uniformity of the results is represented by the slope of the straight portion of this curve; and that some results will fall considerably below and some above this line, producing the curved departures at the end.

A point worth mentioning in this connection is that we must contend not only with the variations in strength between different brands of cement, but there is the additional variation in the strength of any particular brand from time to time. The importance of this is well illustrated by Fig. 2, which shows a spread from 270 to 420 lb. per sq. in. in mortar tests of two brands of cement, both of which were manufactured over a period of about eighteen months.

On Fig. 3 this method of analysis is applied to test results obtained from cylinder tests on seven separate construction operations. As in the progressive strength curve of the cement tests, the results are plotted in the sequence of their strength. The various jobs had varying numbers of test cylinders, so that to get the curves on a comparative basis the abscissa had to be re-cast to give all the curves the same termini. To get a general comparison between uniformity of laboratory and field results, two curves have been added showing series of tests made at Lewis Institute. It is seen that in each case analyzed the curve is distinctly comparable to a probability curve replotted to the progressive strength basis.

Curves A, B, C and D show results of field tests on ordinary 1:2:4 concrete mixes with nominal 2000 lb. strength specified. All are 28-day cylinders, except D, which represents 60-day concrete. One job was built several years ago in Brooklyn using crushed trap rock aggregate; another job was built in Baltimore with river-dredged aggregates; another job was located in Olean, N. Y., using glacial drift aggregates; and the fourth was a New York City operation in which Hudson River limestone gravel was used. Curve E of the Hydro-Electric Power Commission of Ontario represents results published by Young in *Engineering News-Record* of April 13, 1922, of their Class C (1500 lb.) concrete, in which 2½ in. crushed dalomitic limestone was used.

It is quite remarkable that five jobs so widely scattered and built under such different conditions should produce results so closely related yet in themselves varying so widely. It is apparent that this 1:2:4 concrete, nominally 2000 lb., could from a critical standpoint scarcely be given a higher rating than 1500 lb. material at 28 days. We should remember, too, that these jobs were large operations on which unusual care and talent were used; and they undoubtedly produced better than average results. The four jobs using the 1:2:4 mix averaged 1850 lb. over-all; none of them would have passed the requirements of the Tentative Joint

TABLE III.—COMPARISON OF UNIFORMITY OF TEST RESULTS OBTAINED IN PRACTICE.

Job.	Age, days.	Individual Specimens or Averages.	Extreme Variation.				Straight Line Variation (Omit Extremes).				Mean Variation from Average, per cent
			High.	Low.	Average.	Per Cent Spread of Average.	High.	Low.	Average.	Per Cent Spread of Average.	
A. 1 : 2 : 4 Mix	28	Individual	2615	1210	1852	76	....	....	....	76	21.0
B. 1 : 2 : 4 Mix	28	Individual	2671	1436	1925	64	2300	1500	1900	42	16.4
C. 1 : 2 : 4 Mix	28	Individual	2700	1312	1797	77	2120	1400	1760	41	9.6
D. 1 : 2 : 4 Mix	60	Averages	2950	1102	1940	95	2650	1200	1925	75	21.4
E. Young's Cl. C. (1500 lb.)	28	Individual	3294	877	1887	128	2300	1300	1800	56	19.4
F. Young's Cl. B. (2000 lb.)	28	Averages	2937	1365	2315	68	2800	1870	2335	40	14.4
G. 1 : 1½ : 3 Mix	28	Individual	2730	1650	2160	50	2600	1720	2160	41	10.4
Abrams—22 Brands of Cement	28	Averages	4130	1700	2770	88	3350	2080	2715	47	15.2
Abrams—Fineness modulus tests	28	Averages	3300	2680	2990	21	3150	2850	3000	10	3.41
Briquette Tests:											
Cement, Brand A	28	Individual	406	296	346	32	385	312	349	21	5.5
Cement, Brand B	28	Individual	422	270	331	46	405	294	331	33	8.3

Committee Specification for 2000 lb. concrete even with the tolerance suggested by Committee C-9 of the American Society for Testing Materials, which requires 75% of the specimen to have 80% of the design strength.

Curve F of the Hydro-Electric Power Commission of Ontario gives results published by Young in *Engineering News-Record*, March 17, 1921, with their Class B (2000 lb.) concrete; it runs fairly close to Curve G, representing tests on a building operation in New York City using a 1:1½:3 mix. The results obtained by Young, while not marked in their uniformity, gave numerous very high strengths for lean mixes. It would be interesting to know to what extent the large-sized aggregate, in this case 2½ in. crushed granite, contributed to this end.

These results appear to support the contention that ordinary 1:2:4 building concrete is as a matter of fact 1500 lb. concrete at 28 days; and that it really takes a 1:1½:3 mix with small aggregate to produce 2000 lb. concrete at 28 days on building work with any degree of certainty.

In Table III statistical comparisons are made of the nine progressive strength curves presented in Fig. 3. It will be seen that for the field operations the over-all spreads between high and low results range from 50% to 128% of the average. Neglecting the extreme low and high results and confining ourselves to what might be called the straight-line variation, the spreads run from 40% to 79% of average. A point of interest is that Curve E the 1500 lb. concrete of the Hydro-Electric Power Commission of Ontario while showing the greatest lack of uniformity overall, namely 128%, shows a straight-line variation of only 53%. Again, four of the field operations show a straight-line variation of between 40 and 42% of average; and the tensile tests of cement show between 21 and 33% of average. Although no scientific comparison is possible, this would tend to indicate that a considerable part of the variation in concrete strengths is traceable to the variations in the cement.

The Question of the Concrete Yardstick.—There is a serious question in many minds as to the propriety of the 28-day cylinders as a true measure of concrete strength. It is undoubtedly true that in many cases a large appreciation in strength takes place after the 28 days have elapsed; still a better substitute has not yet been found. The suggestion is frequently offered that cores cut from the actual structures are a more representative measure. On this question the curves given in Fig. 4 are of interest. They represent comparisons between molded cylinders and drilled cores as obtained by the Pennsylvania Highway Department, published by Mattimore in *Engineering News-Record*, Jan. 1, 1922.

As to the comparative uniformity of cores vs. cylinders, it will be seen that the cores show no striking improvement in this respect. But the results do indicate that the concrete weakest at 28 days gains most in strength with age, its handicap at 28 days being largely overcome. By comparing lines AA and BB, it is clearly evident that the increment in strength after 28 days is greatest for that concrete which is weak at 28 days.

This same phenomenon we have noticed on several other operations,

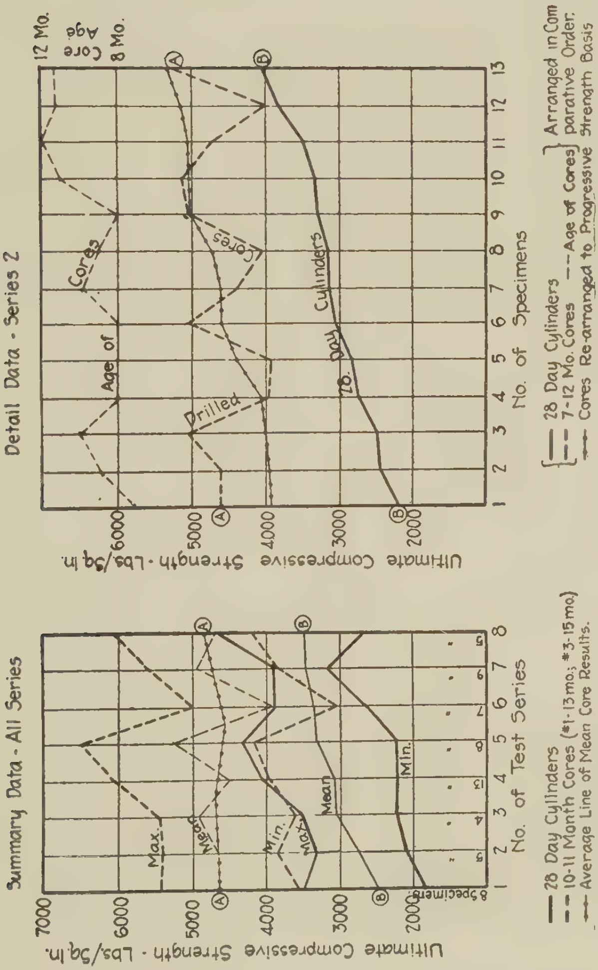

FIG. 4.—TEST RESULTS OF H. S. MOTTIMORE, PENNSYLVANIA STATE HIGHWAY COMMISSION, MOLDED CYLINDER VS. CUT CORE STRENGTHS.
(*Engineering News-Record*, Jan. 12, 1922.)

whose results are omitted for brevity. It indicates that judging concrete by 28-day cylinders may lead to very unjust results, and that 60-day check cylinders may often be justified.

It is not the thought that the information herein submitted can be used scientifically in any definite quantitative way; rather it is a reminder of the complexity of the subject from the job standpoint, with some suggestions of points to be watched by the construction man who is troubled with erratic test results. Our immediate problem is to collect additional data of this kind by which the application of proposed tolerance rules may be judged.

That the present rule of thumb methods of manufacturing concrete are susceptible of much improvement, and that we will see more uniform concrete in the future is almost axiomatic. The introduction of better methods and apparatus should and will proceed apace; this is simply a repetition of human history. Still, the large number of factors involved, many of them beyond job control, should suggest a deliberate advance and give pause to the tendency to expect too radical an improvement in one jump.

DISCUSSION.

P. J. FREEMAN.—I have been very much interested in this paper, as we have tested many thousands of field specimens, the results of which varied greatly. We are always wondering why they do vary. Mr. Freeman

We have been testing field specimens from one job where the 1 : 2 : 4 mix has been the same for three years, but with the same supervising inspectors there is still a much wider variation between individual specimens than would be expected by the average engineer or architect. Some time ago a number of specimens showed a strength of about 700 lb. per sq. in. at 28 days. It was obvious from the broken pieces that the specimens had not been properly made, but they were the only ones representing that particular section of concrete. The engineer immediately had about twenty cubes cut out from the finished work and the crushing strength was found to be over 2800 lb. per sq. in., at 30 days, thus demonstrating that the test specimens did not correctly represent the quality of the concrete.

On many jobs the specimens frequently pass through several hands and some one may be careless and allow a specimen to dry out or even freeze and thus the specimen does not truly represent the concrete as poured. It has been my experience that the engineer or architect is strongly inclined to hold the contractor in such cases and it is not always possible to cut out test specimens to decide the issue.

A sufficient number of test specimens should be taken and the contractor required to meet an average strength specification, but a certain percentage of specimens should be permitted to fall below these requirements before the job is rejected. I am heartily in favor of specifying a strength for concrete whenever the time comes that we can do so, but in working up to that we must provide a safety valve to protect the contractor. If an allowance is not made for variations in specimens, the contractor will frequently be blamed for conditions which do not exist in the finished concrete as poured into the forms.

JOHN A. FERGUSON.—I would like to tell of an experience I had in connection with concrete that had attained the age of eight years and then began to disintegrate, the experience was in many respects quite similar to the experiences of Mr. Freeman. Mr. Ferguson.

A bridge about 500 ft. long and having a main arch span of 150 ft. had been built eight years before the time when I had been called into the problem. The concrete was disintegrating in many places. Some thought that the whole structure might become unsafe in a very short time but a careful examination brought out the fact that only certain parts were giving evidence of the rapid disintegration. The concrete had been placed under very competent supervision, and the records of this work were unusually complete. Some had been placed in quite cold weather, some had been cast in fair days, and the temperature had subsequently fallen

Mr. Ferguson. very rapidly and unexpectedly below freezing and remained there for some days or weeks. Other concrete had been placed after the first of May and the weather was subsequently warm. The records showed that the proportioning had been done very accurately for a time nine years ago.

Some that was placed after the first of May became so badly disintegrated that chunks of it fell to the ground, and much of it had every appearance of being about ready to fall. Curiously enough, the concrete that had the least attention during the cold weather was sound in every particular, that which had been placed in warm weather at about 70 deg. was in such condition that it had to be removed, and replaced with new concrete.

The lesson that was drawn from the experience was that while the concrete had been very well proportioned and every care taken in mixing, the materials became separated in depositing in the forms, to such an extent that water could percolate through the body of the members of the bridge and the percolating water was able to dissolve out much of the free lime. The sand had come from a source that was subject to contamination with sulphur. The chemical and physical examination of the materials disclosed the following truths:

The concrete that was badly disntegrated would dissolve very slowly in distilled water, as shown by the analysis of the water after the concrete had been immersed for two weeks. The surface of the poor concrete had a white efflorescence that analyzed to be calcium sulphate. It was concluded that the percolating water formed a very mild sulphuric acid with the sulphur anhydride remaining in the sand. The proportion of this mixture followed almost the proportion of the aggregate as shown by the surface area calculations, leading to the logical conclusion that the sulphur came from the sand and gravel.

Mr. Upson. M. M. UPSON.—We ought to approach a greater uniformity in the production of concrete. The problem involves the maintaining of uniform conditions and securing uniform materials.

A year or two ago, I had to do with the management of a cement products company in which it was necessary to maintain a definite compression strength in all the products. This occurred at a time when cement was hard to get. By means of a curve based on the compression strength of different brands of cement, we were able to vary our mix to attain the desired result. This involved a difference of as much as 120% in the quantity of cement used. In other words, it took one and one-fifth times as much cement of, say, brand A as it did of brand B, with a variety of proportons for other brands between these two. All the cements were of standard brands and fully met the specifications of the A. S. T. M. It may be said, with credit to the manufacturers, that each brand gave a uniform result; that is, the compression strength from the same mix on a shipment one month was about the same as that attained from a shipment of the same brand six months later.

I have no doubt that the cement companies are fully aware of this variation in the compression strength of different brands and are doing everything possible to secure uniformity. Until this difficulty has been solved, it is, of course, impossible for the producer of concrete to be sure of the strength of his product. Mr. Upson.

F. E. Richart.—The Institute has devoted considerable time to the topic of better concrete; I think that might well be stated more uniform concrete; that is really the thing that is concerning most of us. Even in laboratory investigations we find a great many things that are difficult to explain and a great many irregularities and seemingly inconsistent things which come up. Mr. Richart.

I was interested particularly in the comparison given between cored specimens and molded cylinders. There is very little information at present available on the comparative strength of specimens of the two kinds. The comparison made in this paper, I believe, was rather hard to follow because of the difference between the age of the cored specimens and that of the other specimens. I have had occasion to make comparisons between drilled specimens and the ordinary molded specimens made from road concrete, and I was interested to find that in practically every case the cored specimens developed a compressive strength considerably greater than that of the molded specimens. This was true considering the fact that the molded specimens were made and stored right with the pavement and had as nearly as possible the same curing conditions, and were tested at the same age as the cores. The cored specimens were made up so that the height was twice the diameter.

These test results indicate that the concrete as placed and finished in the road slab is better compacted and more homogeneous than concrete as molded in the ordinary test cylinder. The cores, therefore, should show the smaller range of variation in density and strength. I would like to say also that where we had a chance to cut cored specimens from road concrete of different ages, the cored specimens showed a very marked increase in strength with age up to a period of several years. From this it appears that road concrete may be expected to receive the necessary moisture to insure a continued gain of strength with age.

R. B. Young.—I would call attention to the fact that the Class B concrete referred to in Mr. Bloecher's paper and which he has compared to a 1: 1½: 3 mix had average proportions of about 1: 2: 4 and the Class C concrete of about 1:2½:5, somewhat leaner than the concretes to which they are compared. Mr. Young

Report on Field Tests and Methods Used in Building Construction to Obtain Concrete of Specified Strength.

By J. G. Ahlers.*

These tests were undertaken to obtain information on the practical workings of the information published by the Lewis Institute of Chicago, and the subsequent proposed specifications for concrete and reinforced-concrete by the Joint Committee on Concrete and Reinforced-Concrete. The possibility of obtaining concrete of a uniform and required strength is a matter of controversy and if it is practical to obtain same in field work has not yet been definitely proven.

An attempt is now being made to apply these theoretical methods on a building operation at Yonkers, N. Y., for the Alexander Smith & Sons Co., on which the Barney-Ahlers Construction Corporation are contractors.

The following items are of interest in the test:

1.—A review was made of the factors entering into the strength of concrete and it was found that there were a great many variables. The tests, however, have been based on an assumption that strength of cement in compression is uniform and only one brand has been used throughout. The large factors entering into the variation of strength are those of cement water ratio and fineness modulus of the aggregate.

2.—The methods of arriving at the fineness modulus of the aggregate have been fully described in Bulletin No. 1 of the Lewis Institute, and the details entering into the determination of fineness modulus will not be considered in this report. All the work in this connection has been done, however, in accordance with the recognized standards of the Lewis Institute.

3.—Preliminary study of the building operation included a survey of the aggregates available for reinforced-concrete. The question of the use of pre-mixed aggregate, or the so-called "Ready Mix," as against the use of separate sand and gravel, was studied both for economy, ease of handling and uniformity of material.

As the question of using "Ready Mix" versus separate sand and gravel, to obtain uniform strength of concrete, had been raised by members of the Joint Committee, it was deemed desirable to make a series of tests to compare the two methods of handling and mixing concrete and aggregate.

This report confines itself largely to tests to determine this point, due to the lateness of the season and delay to the work. Also the question of uniformity of aggregate is very vital to contractors who are anxious to secure good concrete at minimum cost.

*Barney-Ahlers Construction Corporation, New York City.

4.—Material supply was studied thoroughly with the Kittanning Sales Co. who obtain their aggregate from the Great Eastern Dredge Corporation at Pt. Jefferson, L. I.

Great interest was shown by these companies as they realize that by selling a uniform material of a fixed fineness modulus, a better market is secured. At the next convention, if the Board of Direction desires, it will be possible to obtain a report from this dredging company, now

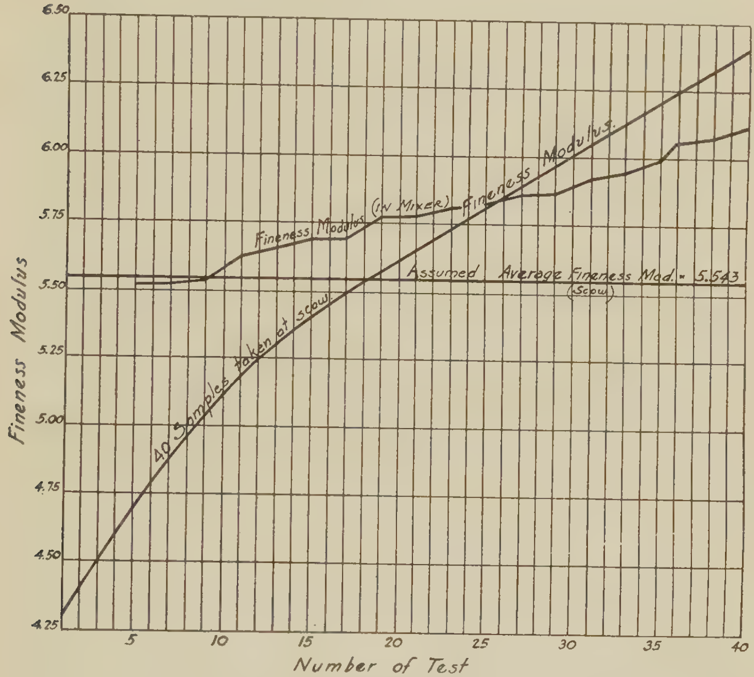

FIG. 1.—ACTUAL AND ASSUMED AVERAGE FINENESS MODULUS OF AGGREGATE SAMPLES.

members of the Institute, on the possibility of securing nearly uniform material.

5.—In order to realize the problem of securing uniform aggregate for concrete, it is desirable to give a brief outline of one type of floating plant used for this purpose. The plant at Pt. Jefferson, L. I., consists of a floating dredge with a 10 in. suction line pumping the aggregate from the bottom of the harbor channel where the material is found very clean, sharp and of a size almost entirely below 1½ to 2 inches.

As shown in one of the views the dredge at the discharge of the suc-

tion line has a flume where the material by going over a bar screen rejects all above $1\frac{1}{2}$ in. diameter, and thereafter by passing over a $\frac{1}{4}$ in. screen separates gravel from fine aggregate.

At the present time the only graduation that is made is above and below $\frac{1}{4}$ inch. The material thus separated is put in bins and from these bins, by adjustment of the gates, materials are allowed to run out in the

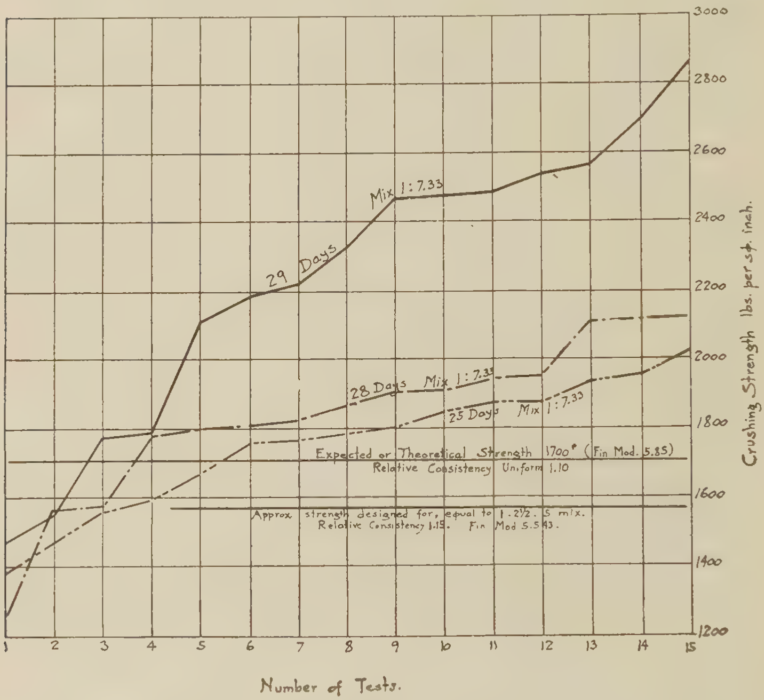

FIG. 2.—STRENGTH OF THREE SERIES OF FIFTEEN CYLINDERS TAKEN ON SUCCESSIVE DAYS.

proper proportions, carried on a belt conveyor, thereby mixed together, to the scow alongside.

The intention of the dredging company for the coming year is to build and equip a plant that will separate the material into seven sizes, and thereafter by following the fineness modulus theory, recombine these in such proportions so as to secure a perfect concrete aggregate. The surplus of any size can be rejected or sold for special purposes such as roofing gravel, sand for mortar, road gravel, etc.

It is well worth noting that if such results are obtained, the work of the American Concrete Institute for the benefit of the concrete industry

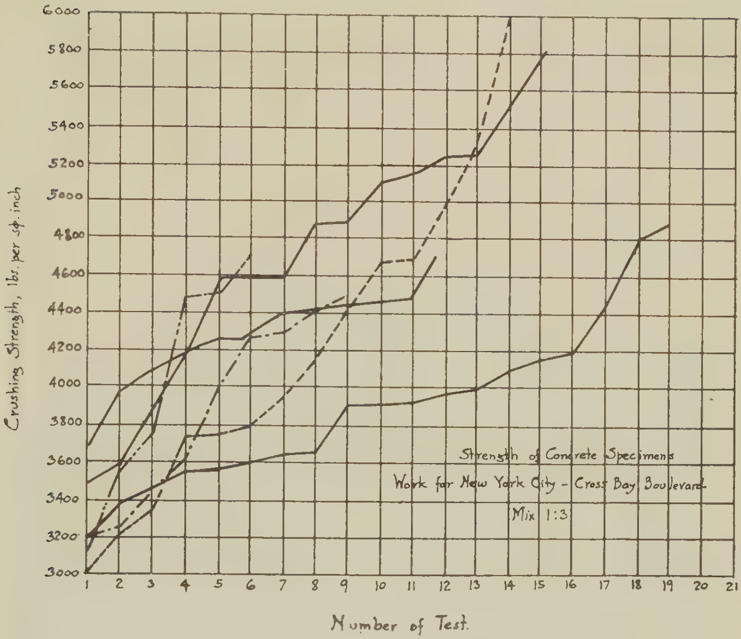

FIG. 3.—VARIATION OF MIXED SAND AND GRAVEL FINENESS MODULUS.

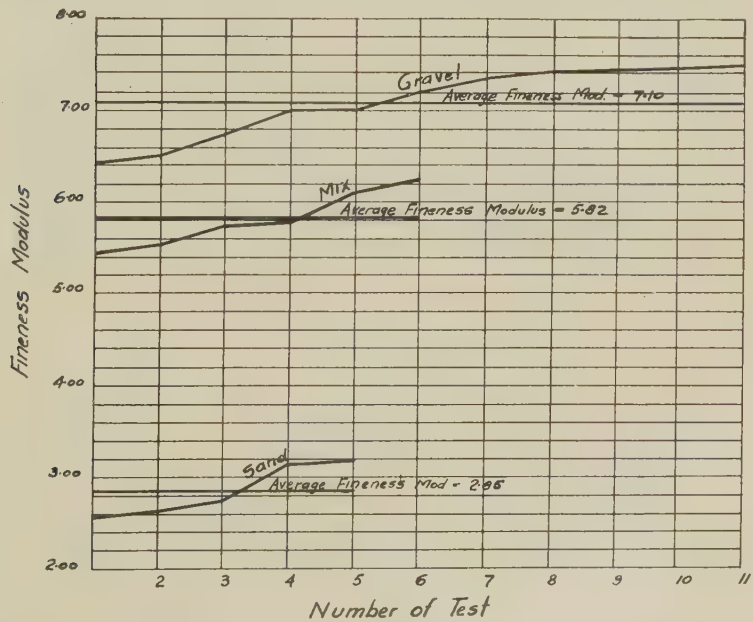

FIG. 4.—STRENGTH OF CONCRETE SPECIMENS ON NEW YORK CITY CROSS-BAY BOULEVARD.

in New York City alone will have resulted in a large step forward securing concrete of nearly uniform strength.

The writer took a series of samples at the dredge at short intervals, also a series of samples at the time of dumping aggregate in the mixer, this to obtain the variation in fineness modulus from the time of dredging until entering the concrete mixer. These samples were sent to Hunt Laboratories for a test and the result of these tests are shown in Fig. 3, for both sand and gravel and "Ready Mix."

To obtain an idea of the condition of the aggregate on the barges on

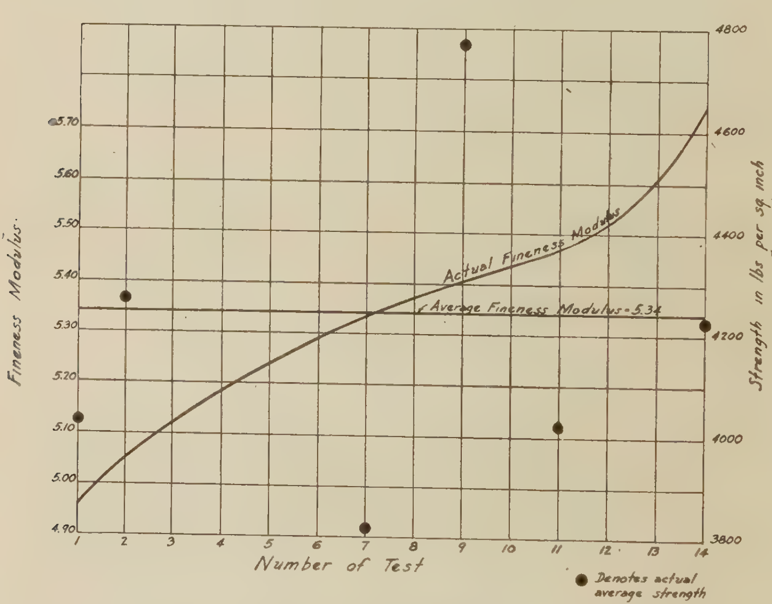

FIG. 5.—AVERAGE FINENESS MODULUS OF DIFFERENT BARGE LOADS OF READY MIXED AGGREGATE.

arrival at the point of unloading, after towing from the dredge, a series of fifty samples were taken at various parts of a scow containing "Ready Mix," results of which are shown on Fig. 1, giving the variation of fineness modulus from 4.30 to 6.37.

7.—In designing the concrete on the work for Alexander Smith & Sons Co., the average fineness modulus obtained from the samples taken at the barge at the point of unloading, as shown in Fig. 1, 40 samples were taken at all points about one foot under the surface. The average fineness modulus was found to be 5.543 where material was undisturbed.

Specifications for this work were drawn so as to call for either a certain mix or such other mixture as might be expected to give a selected

theoretical strength in accordance with Bulletin No. 1 of the Lewis Institute, this without guaranteeing to obtain any given minimum strength.

It was assumed that 1 : 2½ : 5 concrete would be 1500 to 1600 lb. at twenty-eight days, and working from the table in Bulletin No. 1, mix of 1 to 7.33 was assumed to give this result for a relative consistency of 1.10, and the average fineness modulus of the 40 samples of 5.543.

8.—In order to see whether this assumed average fineness modulus

FIG. 6.—RUNNING AGGREGATE INTO MIXING PLANT.

was correct, knowing that the material was being more thoroughly mixed in handling from the barge to truck, thence to the conveyor and into the bin and from the bin into the mixer, and expecting the fine and coarse to be in better proportion when going into the mixer than at the dredge or at the point of unloading, twenty-five samples were taken of the aggregate as it was discharged from the gate of the bin into the mixer. Results of these tests are also shown in Fig. 1, called fineness modulus in mixer.

The increased value of fineness modulus found in these last samples may be explained by the fact that of the samples taken at the barge before

unloading, some were probably at points where amounts of fine aggregate might have accumulated, and these last twenty-five samples were therefore a more true indication of conditions.

On the basis of the higher average fineness modulus of materials going into the mixer about 5.85, a greater strength was expected. (See Fig. 2) namely 1700 lb.

9.—To check the results of the design, three series of fifteen cylinders

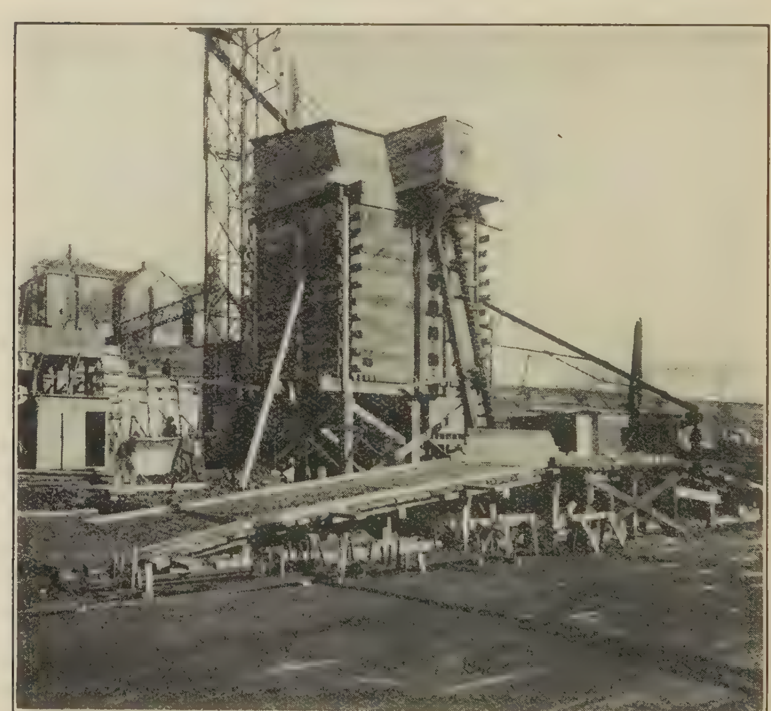

FIG. 7.—ANOTHER VIEW OF AGGREGATE STORAGE PLANT.

were taken on successive days. The result of these tests show the strength at 25, 28 and 29 days, as indicated on Fig. 2. The theoretical strength designed for is shown.

The few cylinders showing a strength below that expected were poorly made, as reported by a testing laboratory and should not have been included in the test.

All the cylinders tested at 29 days show a greater strength than the other two sets. The samples of this concrete were taken on a section of slab poured on a cinder fill about 25 minutes after the concrete was put

in place, and a large amount of excess water had been drained off. For a lower relative consistency a higher strength would be expected and this is what the 29 cylinders show.

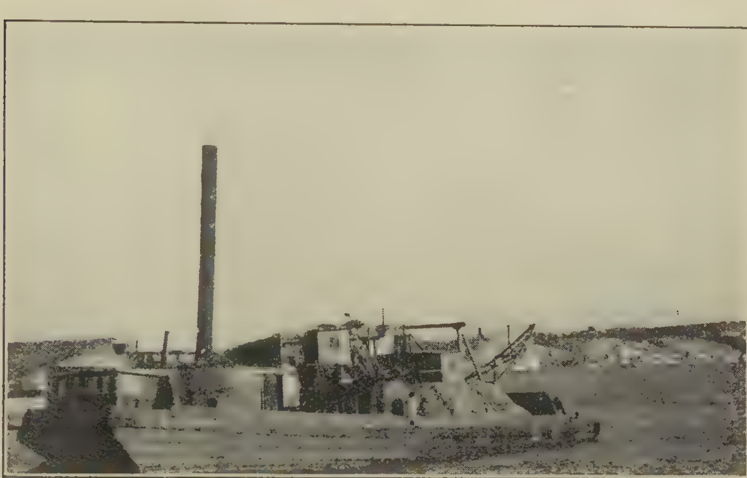

FIG. 8.—BARGE LOAD OF READY MIXED AGGREGATE.

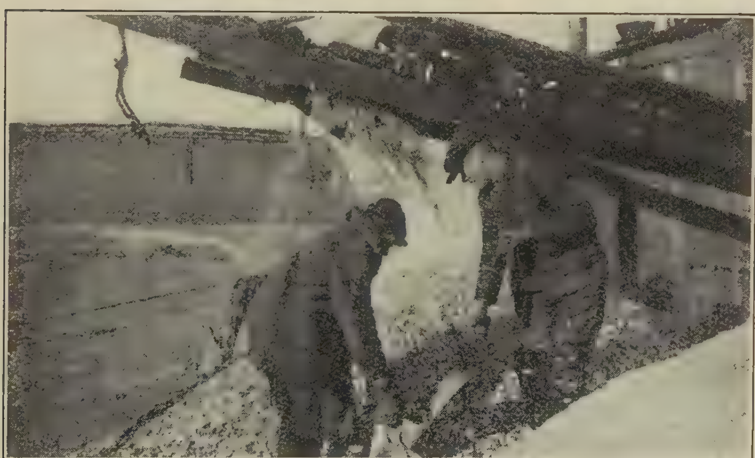

FIG. 9.—TAKING SAMPLES FROM BARGE DISCHARGE.

10.—To check the analysis of "Ready Mix" with separate sand and gravel a series of analysis were made of samples taken at the point of loading of one barge of 1/3 sand, 1/3 gravel and 1/3 "Ready Mix." The results are shown in Fig. 3.

The variation of fineness modulus at the mixer, as shown on Fig. 1, was from 5.52 to 6.10 or a variation of 9.5%. The variation of the cylinders as shown on Fig. 2 was from 1600 to 2000 lb. (if the poorly

FIG. 10.—ANOTHER VIEW OF TAKING SAMPLES.

FIG. 11.—WASHING THE READY MIXED AGGREGATE.

made cylinders are rejected) or 2 percent. The variation of the sand and gravel separate was from 6.42 to 7.50 or 14.4% as shown in Fig. 3.

11.—From the point of view of field operation, it was found impractical to use sand and gravel as separate ingredients, due to unloading

conditions at the bulkhead. The job could not be supplied rapidly enough by unloading two materials separately as it necessitated moving the barges around a great deal.

In view of the above results it was decided to use "Ready Mix" aggregate throughout.

12.—From the result of the test cylinders, it would seem to be possible to get fairly uniform results in strength although no contractor could guarantee to obtain any minimum strength, as a knowledge of the strength of this concrete could not be had until a long time after the slabs were completed.

13.—Permission has been obtained from Mr. Rice, of the Bureau of Highways, City of New York, to present some of the test results obtained on the Crossway Boulevard to Rockaway.

These show the results of trying to overcome some of the impractical working conditions under the proposed new specifications. Fig. 4 and 5 indicates a mix that was required in order to get a guaranteed minimum strength of 3000 lb. at 28 days.

For a mixture of 1 : 4½ an average of 3000 lb. would probably have been obtained whereas the contractor had to use a mix of 1 : 3.

Fig. 5 shows an average fineness modulus of fourteen different barge loads of Ready Mix, indicating the variation from 4.95 to 5.75.

The average strength of cylinders taken from some of these barges is indicated by the black circle for such a barge, and it will be noted that the strength has no definite relation to the average fineness modulus.

14.—From tests at the building operation at the Alex. Smith Co. by Barney-Ahlers Construction Corp. we hope, by another year, to have test cylinders showing the relation of strength at 28 days, 60 days and one year to a designed strength from which conclusions might be formed as to safe ratios of the value used in design and actual results obtained in the field. It may be possible to take certain core boring to show the comparison in strength of the concrete in the structure to that of the test specimens.

15.—From experience on this building operation, it seems that the use of "Ready Mix" with a fairly uniform fineness modulus is reasonably sure to give uniform results in the strength of the concrete. It seems safe to predict that with such a uniform aggregate, uniform cement, and definite rules for building superintendents as to the amount of water and mix, that fairly uniform results should be obtained.

It would also seem safe to predict that field operation using such methods will produce concrete in the structure at 60 or 90 days (when the building is being put to use), that will be well above the desired strength. It would seem unwise to advise, however, any contractors to guarantee a guaranteed minimum strength as this would not increase the value of the concrete, but it may be stated that by proper co-operation between designing engineers and the field organization, and by the use of uniform materials, some check on the actual results may always be obtained.

It is necessary, in all field work, to have the methods as simple and without complication as possible, as it will be a long time before any Superintendent or Field Engineer will be able to make his own design of the concrete mix.

16.—Acknowledgment is to be made to Mr. Davis, of the Hunt Laboratories for assistance in obtaining these results; also to the Kittanning Sales Co. for furnishing means of obtaining samples for tests.

The actual field work and field sieve analyses were made by the Barney-Ahlers Construction Corporation who handled this building work. Views attached show field operation, field laboratory, plant, etc.

This report is the preliminary report and will be submitted in full if the Board of Direction wish a complete review next year.

DISCUSSION.

F. R. McMillan.—What do the curves in Fig. 1 represent? **Mr. McMillan.**

J. G. Ahlers.—The points on these lines are the fineness modulus on forty samples taken at the barge and plotted for each sample from small to large. The fineness modulus might have been shown as a horizontal line for each of these spaces. The average fineness modulus of the forty samples worked out a little over 5.50. The upper line shows the actual fineness modulus in the mixer of the material as it went into the mixer. **Mr. Ahlers.**

F. R. McMillan.—Am I to understand from those two curves that in the process of transferring from the boat to the yard, you increase the fineness modulus? **Mr. McMillan.**

Mr. Ahlers.—No, the fineness modulus had not been increased; that is impossible. I think it has become more thoroughly mixed and hence better graded. **Mr. Ahlers.**

Mr. McMillan.—How does it happen that one lies above the other? **Mr. McMillan.**

Mr. Ahlers.—These forty samples taken at the boat were deliberately taken of both fine and coarse so as to show the variation existing in the aggregate and to get an average before it was unloaded from the boat, shown in the steep curve and showing a wide variation. After it was unloaded, it was brought to the plant and as it went into the mixer another set of samples was taken shown in upper line and presumably the latter is more nearly a true condition. **Mr. Ahlers.**

Mr. McMillan.—Does the first set of samples represent the average fineness modulus of the barge? **Mr. McMillan.**

Mr. Ahlers.—Yes, as it was estimated based on information gotten out of those fifty samples. **Mr. Ahlers.**

Mr. McMillan.—They were supposed to be taken so that they would represent the average fineness modulus of the large load? **Mr. McMillan.**

Mr. Ahlers.—Yes, taking samples of good and bad as it came. **Mr. Ahlers.**

Mr. McMillan.—And then the second series would represent the fineness modulus on the job. **Mr. McMillan.**

Mr. Ahlers.—Yes, based on samples as they went into the mixer. The reason the other line is low came from the fine samples gotten by deliberately hunting out the worst spot, both fine and coarse, on the barge and getting that particular sample, so as to get an average. **Mr. Ahlers.**

Mr. McMillan.—Then the lower curve does not represent the average on the barge? **Mr. McMillan**

Mr. Ahlers.—That is not the average, but was used as the average in computations. **Mr. Ahlers.**

Mr. McMillan.—The point is, then, that there is no relation between these two sets of curves; one was a deliberate attempt to get the worst sample and the other an accidental attempt to get what came. **Mr. McMillan.**

Mr. Ahlers.—Yes, there is a relation; a statement was made to me in New York last fall that it was not practical to use ready mixed aggregate because, due to the movement of the boat, etc., the material would segregate so much that it would not be of any uniform gradation when you **Mr. Ahlers.**

Mr. Ahlers. used it in concrete. I have by these plats attempted to show that the uniformity of the aggregate as it goes into the mixer is of a variation so slight that it does not have any appreciable effect on the resulting strength of the concrete, whereas, if you take the samples on the barge, it is perfectly possible to get such variations that by first offhand judgment you might condemn the materal as not being practical for concrete.

Mr. McMillan. MR. MCMILLAN.—I would like to make the point that the samples taken in two different ways with the evident intention of accomplishing two different things do not show the thing you are desiring to show.

Mr. Howe. H. N. HOWE.—How often were those samples taken at the mixer? In other words, how representative were they of the actual mixture?

Mr. Ahlers. MR. AHLERS.—I think those samples were taken within three hours' time; about as fast as it was practiced for the men to take them. A bagful were taken in each case, and that was reduced down by quartering into a typical sample of that aggregate.

Mr. Hollister. S. C. HOLLISTER.—As I understand these curves, the horizontal line is substantially an average of the value shown in the steep curve?

Mr. Ahlers. MR. AHLERS.—That is right.

Mr. Hollister. MR. HOLLISTER.—And if a horizontal line were drawn for the second, but less steeply inclined, curve, it would lie somewhere around 5.8?

Mr. Ahlers. MR. AHLERS.—That would be about right, yes.

Mr. Hollister. MR. HOLLISTER.—What would be the significance then of the second horizontal line at 5.8 as compared to the first horizontal line?

Mr. Ahlers. MR. AHLERS.—It would be a more true indication of fineness modulus of the aggregate and would show a saving in the mix; in other words, the mix could have been leaner because the fineness modulus was higher, the results from upper line were not available at time of mixing and I hoped to be on the safe side when in proportioning for the concrete I used the average taken from the barge, which you see is the case. That is one reason the results in the test cylinders show a higher strength, I believe, than was anticipated in proportioning the mix.

Mr. Hollister. MR. HOLLISTER.—Do these sets of curves represent substantially the same aggregate or the same character of aggregate?

Mr. Ahlers. MR. AHLERS.—Absolutely the same boatload.

Mr. Hollister. MR. HOLLISTER.—In both cases, an earnest attempt was made to get a good average sample of the whole lot of aggregates.

Mr. Ahlers. MR. AHLERS.—That is right.

Mr. Hollister. MR. HOLLISTER.—Then why should this difference occur in forty samples?

Mr. Ahlers. MR. AHLERS.—Because in getting that average, probably undue weight is given by these low fineness moduli which represent some of the fine material that had separated from the coarse, and which naturally, when it was mixed up in the bin would not have any weight in the resulting fineness modulus of the material as used. Therefore the average fineness modulus would be higher than that of these individual samples. That is perfectly obvious.

Mr. Abrams. D. A. ABRAMS.—What would be your judgment as to the average value

you might get for the fineness modulus? Suppose you built samples from a dozen different scows of material. Mr. Abrams.

MR. AHLERS.—I think that shown in Fig. 5 where the city had taken samples on, I think fourteen different barges. There the fineness modulus varied from 4.95 to 5.75, and the average of each of those boats went within those lines, which would show a rather uniform fineness modulus. Mr. Ahlers.

RICHARD L. HUMPHREY.—Were these samples taken during fair weather conditions? Mr. Humphrey.

MR. AHLERS.—The samples were taken by digging into the edge of the pile on the boat where you would assume the material had not been very much disturbed. Mr. Ahlers.

MR. HUMPHREY.—I mean the samples at the mixer. Mr. Humphrey.

MR. AHLERS.—They were taken just as you open the gates and it chutes down. Mr. Ahlers.

MR. HUMPHREY.—I am asking about the weather conditions, whether you had rain or not. Mr. Humphrey.

MR. AHLERS.—That bin is entirely covered, there is a roof over the top, and material when it once gets into that bin, is free from rain. Mr. Ahlers.

MR. HUMPHREY.—But the barge was not covered? Mr. Humphrey

MR. AHLERS.—No, sir. Mr. Ahlers.

MR. HUMPHREY.—Was it dry weather during the time these tests were made and from the time the barge left the point of origin to the point of delivery? Mr. Humphrey.

MR. AHLERS.—The moisture would not have any influence on the fineness modulus, because it is all thoroughly dried before it is taken. Mr. Ahlers.

MR. HUMPHREY.—I think the speaker will admit that if you had a violent rainstorm between the point of origin and the destination, you could wash the fine material away from the coarse and you would not expect the average of the uniformity proportions throughout the load on the barge to be what the uniformity was when it started, but the question is whether the separate portions were uniform when the material is handled under rainy conditions, which has nothing to do with the separation in handling on the work. Mr. Humphrey.

MR. AHLERS.—I believe it would, because as I said before, the samples were taken about a foot under the surface, on the slope at the side of the barge. If you notice a bargeload of aggregate loaded at its point of origin, by the time it comes into New York when the good barge captains have been walking over it and throwing some overboard, etc., the slope is changed but not enough to affect the material about a foot under the surface. That is the reason we dug down and took it a foot under the surface. I will admit that the top foot might be somewhat changed in graduation from the material as loaded at the dredge, but that is not what this was intended to bring out. All material after it is brought to the job has been mixed three or four times when it goes into the mixer, would be fairly uniform as far as fineness modulus is concerned. Mr. Ahlers.

M. H. FREEMAN.—I would like to ask Mr. Ahlers if there are any difficulties in unloading the barge or in transportation and storage. Mr. Freeman.

Mr. Ahlers. MR. AHLERS.—I think in this respect we are learning every day. The material when loaded on the barge is brought on a belt conveyor from the bins at the storage hopper where it is produced and deposited on the barge in a heap. Naturally some of the coarse aggregate will run off and the fine stay, but the average pile is levelled off and the boat is trimmed and brought by a tug boat to the point of unloading. This usually is at a bulkhead where a derrick with a grab bucket will unload. These material dealers now attempt to have that derrick unloaded, not all in one place but like taking slices off a loaf of bread, taking it from the end of the barge and dumping it in the hopper. Here it is mixed and goes through into motor trucks. The trucks usually bring it up to a belt conveyor that dumps in a bin. In the bin it is spread out fairly uniform, also from the top, in the form of a cone. As the gates in the bottom of the bin are opened the material runs out of that bin pulling the material almost in the reverse shape of the cone built up in the top of the bin, and so you get the material in the mixer.

Mr. Freeman. MR. FREEMAN.—I asked that question particularly because in using aggregate of this character a few years ago, we found that in handling it in the ordinary clamshell bucket and transferring it to the mixer and dropping it into the mixer, that instead of mixing, it rather tended to separate, that the cone which forms in the hopper tended to allow the coarser aggregate to go to the side, and our samples taken before going into the mixer, spread instead of mixing. In mixing our specified mix of 1 : 2 : 4, it was 1 : 1½ and 1 : 1. Those are odd batches. Many of the batches were all right, but we did not find the practical uniformity that the speaker referred to.

Mr. Irwin. A. C. IRWIN.—Were the samples from the bin taken when the bin was full and continued till it was empty?

Mr. Ahlers. MR. AHLERS.—No, that condition would arise only if your superintendent is lax and lets his bin run empty, does not have material ahead.

Mr. Irwin. MR. IRWIN.—You are always sampling from a full bin then.

Mr. Ahlers. MR. AHLERS.—Well, I would say about half full.

Mr. Irwin. MR. IRWIN.—And the gate was in the bottom of the bin, in the center?

Mr. Ahlers. MR. AHLERS.—Yes.

Mr. Irwin. MR. IRWIN.—You really were sampling from the vertical of the whole?

Mr. Ahlers. MR. AHLERS.—Yes, well, sampling the material as it came in; it has all got to go out through the one gate.

Mr. Irwin. MR. IRWIN.—But the point is that you were sampling really from one general location of the bin, and if there was a ravelling of the aggregate due to dumping it into the form of a cone in the bin, you were not getting the revealed aggregate of the sample.

Mr. Ahlers. MR. AHLERS.—That is precisely what the result of the fineness modulus shows. We took them all day long for a week running, and as you see the results do not vary very much. The material is mixed as it goes into the bin and as it comes out, because you are not taking any part of it out of any particular part of the bin. It has all got to come out the same way if you only use the one opening.

Design and Construction Features of the Ideal Section of the Lincoln Highway.

By W. G. Thompson.*

The Lincoln Highway Association is a non-profit corporation organized for the purpose of marking the shortest and best line for a transcontinental highway from the Atlantic to the Pacific seaboard. Its work since incorporation has been financed by voluntary contributions from persons and companies interested in development of highways suitable for modern vehicular traffic. Due largely to the association's activities, hundreds of miles have been paved and improved by the states and communities traversed by the Lincoln Highway.

Widespread popular demand for highway construction in 1920 convinced the officers of the association that the necessity for further urging of the building of highways had passed, and gave rise to the idea of constructing a section which should, as nearly as possible, embody those features considered ideal from the viewpoint of the user and owner.

The site selected is on the Lincoln Highway at Dyer, Ind., about eight miles south of Gary and thirty-two miles south of Chicago. One hundred twenty thousand dollars was contributed by a well-known manufacturer, $49,000 by the State of Indiana, and $25,000 by Lake County, in which the section is being built.

Four thousand six hundred questionnaires were mailed by the association to highway engineers in public employ, professors of engineering, and others, requesting suggestions. A summary of these was used as a basis for discussion by a technical committee of highway engineers appointed by the Association to serve, without pay, in formulating the general features of design. Lengthy discussion and deliberation by this committee resulted in the selection of portland cement concrete of 1 : 2 : 3 mixture, laid in one course, for the pavement. Since this phase of the project is presumably of paramount interest to the American Concrete Institute, reasons for adoption of concrete pavement should be made clear.

The Technical Committee unanimously decided to adopt concrete, with no intention of conveying the impression that it is the ideal material. In no phase of human activity is the ideal ever attained. We may briefly define the "ideal" pavement as that one which embodies uniform smoothness, least resistance to tractive effort, durability, absence of skidding properties, and comparatively low first cost and maintenance. The committee decided these qualities were more pronounced in the concrete than in several of the other excellent types in common use.

It is conceded by highway authorities that, on heavily traveled routes, other durable types of pavement surfacing should have concrete founda-

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tions. Concrete has the advantage that it is, at once, foundation and surfacing. Its adoption obviates the dual operations necessary where surfacing and foundation are different, and lessens the initial expense in highway building, with a consequent possible increase in mileage with any given amount of money. It has successfully been demonstrated that, after many years of wear, concrete pavements will serve as a foundation, either for additional concrete surfacing, or other types.

Until the Bureau of Public Roads at Washington, and the State Highway Department of Illinois undertook the conduct of scientific tests, little was definitely known of stresses in concrete pavements, and their origin. Sub-foundation conditions, under concrete pavements, may radically differ every few hundred feet. The designer has heretofore had no reliable information on maximum loads to be carried, or impact forces set up by high speed operation of vehicles. As the above mentioned tests proceed, and governmental regulation of speed and loads becomes more effective, these necessary data will become available and reliable.

The specifications covering width of pavement were predicated upon an average traffic of 15,000 passenger automobiles per 24-hour day, traveling at a speed of 35 miles per hour, and 5,000 motor trucks per 24-hour day, traveling at an average speed of 10 miles per hour. The specifications further contemplated that future highway transportation requires separation of freight and passenger vehicles, as a pre-requisite to safe and expeditious use of the highways; therefore, the Ideal Section should have width for four lanes of traffic, leaving to future police regulations the task of enabling full use of the 40 ft. pavement by compelling vehicles to occupy their proper lanes during congested periods.

Specifications covering slab design were predicated on the ultimate statutory regulation of motor truck design, limiting the superimposed load to 800 lb. per in. of width of tire actually in contact with the road surface, and to 8,000 lb. per rear wheel. Assuming the total rear axle load at 15,000 lb. as 75% of the total gross load, then the total permissible load per truck would be 21,333 lb., which is somewhat under the maximum load now permitted by statute in some states.

Good concrete pavements rarely fail until permanent sub-grade deformation occurs. Foundation conditions at the site were known to be well-drained, and of uniformly high supporting value. Adoption of a slab of 10 inches uniform thickness on a crowned sub-grade was influenced by tests conducted by C. A. Hogentogler, of the Bureau of Public Roads at Arlington, Va. These tests showed that, as representing the average relation of thickness to impact resistance, the 10-in. slab of 1 : 1½ : 3 concrete on a good foundation will resist single wheel impact of 44,000 lb., at least until permanent sub-foundation deformation occurs.

Granting a uniformly smooth pavement surface, a uniformly resistant sub-foundation and uniformly good, unbroken vehicle tires, this figure is well above any impact force to be expected in the near future, especially considering the increasing use of pneumatic tires. Because of their incom-

plete nature, Mr. Hogentogler admits the tests are not to be taken as infallible guides to design. However, the committee believed that, in absence of definite knowledge, the factor of safety was ample, since it was further increased by addition of 80 lb. of reinforcing steel per 100 sq. ft. and introduction of steel dowels through transverse and longitudinal joints. It should be definitely understood that steel reinforcing was placed not because it bore a definite relation to the stresses developed in the slab, but to assist in holding together the several sections should cracks occur. Eight steel dowels ¾ in. x 5 ft. were placed across the transverse joints, two along outer edges, and two on each side of the longitudinal joint to assist in carrying loads at the slab corners.

These provisions admittedly are based on arbitrary conclusions, but are reasonable insurance of the integrity of the slab structure. It not most of our present day pure theory and science in engineering design based upon development and improvement of the practices of earlier builders whose formulae were empirical, and whose conclusions were often arbitrarily drawn?

The endurance of pavement slabs depends in marked degree upon their uniformly smooth surface. Extreme care was exercised to secure a smooth surface, true to grade, on the Ideal Section. Heavy side forms were used, upon which was operated a mechanical tamper and finisher. This was followed by several beltings, using a heavy canvas belt, later followed by long-handled broad-face floats. All slight depressions and elevations were removed until testing by a 10-ft. straight edge failed to discover departures of ⅛ in. from the true grade.

Whole-hearted co-operation of the contractor, the State Highway Department, and the association's engineers made these results possible.

Premolded transverse expansion joints were placed at 75-ft. intervals. A longitudinal joint was placed at the center of the 40-ft. slab. The coefficient of expansion of concrete is of little value in determining the proper spacing of transverse joints. Experience has demonstrated that 75-ft. spacing is as economical, and effective in minimizing cracks, as any other spacing; it was, therefore, adopted.

A graded glacial gravel, all of which passed a 2-in. screen, was used as coarse aggregate with sand having usual standard qualifications.

In order that the sub-grade might be undisturbed after final preparation, dumping and handling of materials thereon was prohibited. The contractor's plant and equipment were selected with care. At a convenient railroad siding two locomotive cranes handled gravel and sand from railroad cars to stock piles. These also supplied materials to movable bins spanning a 24 in. gage track. Six-ton gasoline locomotives, hauling 12 cars each, carrying two tip-over batch boxes, received material from the bins. Three compartments in each batch box accurately measured gravel, sand and cement. Covers on cement compartments excluded moisture during transit. The maximum round haul was about 5 miles. The narrow gage track was laid on the grade outside the side forms.

Batch boxes were handled directly from cars to charging hopper of paving mixer by a boom mounted on the mixer, which was equipped with caterpillar treads.

It will be apparent that wastage of materials was reduced to a minimum by this method, also that accuracy of measurement of materials was assured.

When concrete had set sufficiently to permit, it was covered with straw, which was kept saturated with water for two weeks. Traffic was not allowed on the pavement for thirty days after pouring.

The above very briefly covers the main essentials of the concrete pavement phase of the Lincoln Highway Ideal Section. Its proponents do not set it up as an ideal to be blindly followed. Local economic and traffic conditions will always govern the selection of type and the manner of its building. It is believed the results in this case are good, and that in its general ensemble the project may serve as a help and guide to many communities.

Reasons for adoption of the several other unusual features of the Ideal Section are to be found in *Engineering News-Record*, June 15, 1922. They are too voluminous for presentation here, and are hardly pertinent to the deliberations of the American Concrete Institute.

Trend of Highway Design.

By H. Eltinge Breed.*

The title contains an implication which is an admission—We are not satisfied with the roads we are building. Trend means change in a certain direction, and change involves two factors: inadequacy in present results; and new conditions requiring new adaptation of means to end. The end, or purpose, of roadbuilding is transportation; the means are the vehicles on the road. The new condition arising is the great increase of motor truck traffic for the transportation of short-haul freight and of passengers. In 1917 there were in the U. S. *387,700* motor trucks; five years later, in 1922 they had increased in number to *1,250,000* or 320% plus. Motor cars, in the same period, increased from *4,983,300* to *10,250,000*. Under this tremendous, destructive traffic, costly roads are disintegrating. Obviously, our present roads are in many cases inadequate. What are we to do? The answer would seem simple. We can estimate with fair accuracy the future traffic over a new road. Design that road of sufficient strength to endure it! That, from an engineer's standpoint would be entirely practicable, but not from the taxpayer's to whom the cost would be prohibitive. He must steer between Scylla and Charybdis—the Scylla of demonstrably heavy enough design at too great cost, and the Charybdis of false economy in squandering labor and material upon roads that will go to pieces before they are paid for.

Our problem then which underlies the present trend of design is to plan roads that will sustain heavy traffic and yet last at least during the term for which they are bonded, repaying to the taxpayer in accrued wealth that which is spent upon them. Briefly, we are experimenting, formally at experiment stations, practically on every bit of pavement we lay, to find out how to build the best possible road at the least possible cost. Here are the results so far in respect to the concrete road, to the discussion of which my paper is limited.

Here I pause. This introduction written some weeks ago was followed by a detailed account of the more important of the three hundred odd experiments conducted in the U. S. A. during 1922 which will tend toward the improvement of concrete roads. The subject has, however, been so ably summarized and presented in the Roads Number of *Engineering News-Record*, pp. 55-57, Jan. 11, 1923, and has moreover been so ably discussed at the recent Good Roads Conference that I desisted and scrapped what I had written. One does not wish to pile Ossa on Pelion. A résumé of what has been elsewhere fully reported, the opinion thereupon of a few practical men with whom I have talked, and what seems to me a very important indication of the trend of design is evidenced in the work of Prof. Elmer Hooper, of New York University, which he was

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kind enough to discuss with me—these points, substituted for my former discussion will occupy the few minutes—not more than fifteen—in which you may be interested in attending to this subject.

Underlying the whole trend of design is the effort to oust the trial and error method by establishing scientific procedure based upon ascertained facts.

FUNDAMENTALS OF DESIGN.

1. Fundamental to design of a road is consideration of the load it must carry. Theoretically and practically street regulation of loading is essential in order that we may know for what we are designing. Tests made at the University of Maryland, Purdue University and by The Illinois Division of Highways give us a scientific basis for procedure by proving beyond reasonable doubt that concrete pavements will last indefinitely under repeated loads not exceeding half the modulus of the rupture of the concrete.

2. A second step toward the scientific design of pavements is the plan newly adapted in Illinois and formerly tried in Arizona and California. It marks the change, based upon tests and mathematical analysis, from the slab thicker in the middle and thinner at the edges to one thicker at the edges and thinner in the middle.

3. With less scientific accuracy but persistent practical development is the use of longitudinal joints in concrete slabs held together by dowels.

4. To these changes in design mentioned in *Engineering News-Record* I would add a fourth about which there has been less discussion. With no scientific accuracy at all, but increasing in use, partly as a hope, and partly from proof in service is reinforcement with steel. In order to overcome the weakness from cracks two methods have been followed: one, increasing the thickness of the slab; two, using steel reinforcement. Both are justified within certain limits by service conditions. From the results reported on test actions of road increased thickness has unquestionable advantage. The use of steel in these experiments has not been extensive enough to warrant drawing conclusions.

Steel has, however, been used by practical highway engineers trying to overcome that tendency to weakness in the concrete which is ascribed to lack of tensile strength. The amount used has not been based on calculated stresses but has been determined by results gained from use under service. The use of what in the design of a building floor would be reasonably adequate percents is precluded by the relatively high cost of steel in the design of a pavement. Nor are such large quantities justified in the pavement as are in the floor, for failure in the latter might result in loss of life, whereas breaking of the former causes at worst increased maintenance or replacement.

USE OF REINFORCEMENT.

Reinforcements of all kinds and conditions have been tried, each highway engineer using that style and weight which is most convincing

to him either as indicated by test or by service conditions such as smooth or deformed bars, expanded metal welded or woven mesh fabrics and structural shapes or a combination of these. Weights from 21 lb. per 100 sq. ft. to 150 lb. per 100 sq. ft. with a percent of this in corner reinforcement; dowels; across the ends; along the edges and along the center. In direction the main members run across the slab with the secondary members at right angles or longitudinally along the pavement or vice versa. The ratio of main to secondary member may be anything chosen in the same manner as the style and weight, etc. Why are we so far at variance? Because the conditions for design are indeterminate, and because in order to design we must have something more than a set of variables between uncertain limits on which to predicate such a design. *First* we must know the amount, kind and method of application of loads; *second*, the physical and chemical properties of the materials in combination; *third*, the condition, permanency, and distribution of supports. The first and second of these are easily determined. Our load limits, their application, etc., have been studied as well as the physical properties of concrete under stress and fatigue. The third I will discuss later. Experience shows that cracks will come even though reinforced with much larger quantities of steel than are at present used. Service conditions, however, show a smaller number of cracks when reinforcement is used, even though uneconomical when considered in this light alone. It is certainly useful because we can by the use of steel cut down the distance between the cracks and while the aggregate width of cracks will not be appreciably reduced the individual openings will be proportionately smaller, so small in fact as to prevent vertical movement between adjacent parts for the broken faces are sufficiently rough to remain interlocked. While the theory from which the above statements were evolved may be open to question as are all theories predicated on empirical formulas actual results under service conditions bear out the result of the theory. It is certain that after cracks are found the metal is beneficial. Its initial investment within limits is justified by the saving in maintenance and by increased life.

In addition to these four major changes, regulation of traffic, thickening of edges, dividing longitudinally, and strengthening with steel, there are many minor ones not yet sufficiently developed to make immediate discussion of them profitable.

Minor Changes in Design.

Important to us among these minor changes is the pouring of cracks in concrete pavements with the new compound joint filler invented by the Bureau of Public Roads. It is a combination of resin, rubber and barium sulphate, promises excellent wearing qualities and does not disfigure the pavement because, being the same color as the concrete, it is barely discernible.

With the fundamental principle underlying the trend of design illus-

trated in these changes we must all be in thorough agreement. For engineers by grace of their profession are essentially constructive, combining the spirit of the artist and of the scientist, accepting from the former the goal of perfection, from the latter the goal of truth. There are few of us, however commercially-minded we may be, who, in designing a new road for a community do not envisage for it greater beauty of life; and not one, I think, who would not secure his vision upon a basis of established facts. But in our very eagerness to accept facts upon which to build we need to scrutinize truths which may be misleading because they are incomplete. Sponsors of such findings are usually zealous in proclaiming their limitations but even their cautions may not offset the general human tendency toward mental laziness, easily to accept them as final. I say this the more earnestly because there is a very real danger that in taking decisive leaps we may so discourage the production of certain materials through disuse as to prevent further experimentation along lines of their possible contribution to road building. How much the material producers have furthered our knowledge of road building is beyond calculation.

Limitation of loading sounds like easy elimination of the most important variable in our problem of calculation. Actually it is of the greatest help, but it is not final. Who has not seen a ten ton truck with its load so placed that three-fifths of its weight comes upon a rear wheel with a defective tire? In a Spring thaw on soft sub-soil, even the thickened edge of a concrete slab might crumble under it.

The shift in balance of force from middle to edges leaves still unsolved the necessary strength in the middle.

Convenient as is the building of roads in longitudinal sections, it is by no means certain yet that they will be freer from cracks, or that the dowels themselves may not become sources of destruction.

The use of steel in sufficient quantities for actual reinforcement would cost $16,000 a mile, while in smaller quantities its use is problematical in respect to quantity and in proportion of advantage gained to money spent.

These considerations lead us back to a pertinent and pointed but easily neglected paragraph in the article already referred to.

"Development in Design--Advance in road design has been largely confined to the pavement slab. In all states there seems to be general satisfaction with the present grade cross-sections and finish. Use of standards is the prevailing custom. Very few states as general practice design roadbed for the specific project in hand or to meet the local variations in soil, drainage and location. To repeat, highway engineers appear to be satisfied with their present standard roadbed designs."

Appearances to the contrary, I think we are not satisfied with our roadbed design, and that we have not considered it nearly enough in relation to the design of the pavement slab. Realization of this, though it has had as yet no overt expression, is today, I believe, one of the most important factors in the trend of highway design.

Heretofore, concrete roads in general have been designed in four ways: first, by copying a specification and typical section that was under observation or had had a successful outcome; second, by modification of a partially successful type through correcting the weak points developed in service; third, by special design to meet some of the factors in the immediate problem; fourth, by a combination of all three methods. In none of these methods as far as I know has been serious attempt at estimating accurately the total strength of the road as the result of roadbed plus paving slab. Many tests are demonstrating the exact strength of the slab, but so far we have no accurate gage by which to measure the bearing power of the subsoil. We have guessed at it, and designed accordingly. Many experiments are now being carried out to determine the supporting power of subsoils with varying degrees of moisture, but their results indicate such a wide range of values that we are confronted by two extremes. Either we shall pay much more attention to the road bed or we shall pay none at all.

ROADBED VS. SLAB.

As far as I can ascertain the influence upon design of considering the relation between the roadbed and the paving slab is likely to develop in these two opposite directions.

In the first case, before designing a road at all, the engineers will make a much more thorough study of drainage and subsoil conditions and bearing power of the subgrade. Then we will design, not in terms of miles or even hundreds of feet as we do now, but in terms of slab units, proportioning the strength of each slab to the support it receives from the foundation. Thus, across a stretch of swampy ground the slabs might be designed nine inches thick with steel reinforcement equal to that of a building floor founded on supports while two hundred feet further on, up the sharp ascent of a bill, the slabs may be only six inches thick with slight reinforcement. The high cost of the slabs on unstable soil would be leveled down by the low cost on the firm soil until the average cost of the road would not exceed that of the so-called "average" road today, where slabs on poor soil may go to pieces because of insufficient bearing power, while slabs of the same strength on good soil are over designed for the demands upon them. Concrete paving slabs, no more than individuals, can follow a standardized pattern. The service to the community of both slab and individual depends upon the environment in which it finds itself. Our effort in this direction will be to find the perfect adjustment of the slab to its foundation in order to secure the needed strength. Here, then, we are seeking the closest possible relation between the design of roadbed and the design of the paving structure.

The second tendency is the opposite extreme of this, ignoring completely the mean rut in which we have been traveling. It is to leave the roadbed entirely out of consideration, and with regard for economy devote our energy to getting a pavement structure that will sustain the

demands of traffic upon it. This is the line along which Prof. Elmer Hooper, of New York University, has been working and he has permitted me to present to you here some of his results. I now quote from him:

A PRECAST SLAB DESIGN

"The usual percentage of steel is so small that it is readily acknowledged by most engineers to be of little value in load distribution. Its specified purpose is therefore limited to temperature resistance, bond between adjacent units to prevent vertical and horizontal separation, and strengthening of relatively weak local areas such as corners and unsupported edges. Of these only the temperature stresses seem determinate and at first thought it might appear possible to make calculations to fix the amount of steel to keep intact a predetermined length of slab. It is unfortunate, however, that when stresses develop from temperature change there is very likely to exist at the same time severe stresses from passing loads which, though not causing any increase in the resultant axial stress do cause such a distribution of it as to overburden and rupture those fibers farthest removed from the neutral axis. When the crack starts it has to continue because of the reduced area to resist. Calculations on this basis are therefore of doubtful value. To develop a pavement of positively known qualities it is necessary to make determinate the nature and condition of supports. If and when that condition is established there is no logical reason why a design may not be developed, along the same lines as a bridge or building. It would not be necessary to use such low unit stresses for calculation of a pavement unit since it would not involve serious danger to life and property in the event of failure of a unit. Use of high unit stresses would make possible this type of construction as the quantities would not compare unfavorably with those of present types. Economy would be obtained even with a higher first cost, due to certain long life, due to low maintenance on pavement proper, and due to convenience from continuity of service.

"Along this line the writer has evolved a plan of design and construction, which has for its purpose to satisfy the conditions just discussed. The point of most importance is that the pavement is made up of units, each supported at three points. The supports are solid and carried below frost. Each support carries the ends of one or more adjacent units. Adjacent edges are designed to interlock to make adjoining slabs mutually supporting. It may be readily seen that with this method of support a slight settlement of one end will cause no appreciable change in designed stresses. A tentative design has been worked out in detail, with the idea of making the construction simple, uniform, and in consequence not too high in first cost to make it compare favorably with the present types and designs.

"In the plan proposed the subgrade will carry no load though under excessive deflection there may be contact. There will, therefore, always be a sag or tendency to sag between supports, due to dead weight as well

as to live load. The top surface will be always in compression and therefore not subject to cracking. The bottom will always be in tension so reinforcing metal would logically be used in sufficient amount to develop the full compressive strength of the concrete. Since the supports may be considered as permanent, the moments and shears for given loads may be calculated, and verified by experiment if necessary, with the assurance that service conditions will not alter values. From this date the proper section of concrete as well as quantity and position of steel can be determined.

"The only reasons for the pavement to become inadequate or obsolete are undue reduction of thickness before putting on a wearing surface, or increase in the allowable loading to be carried. Beyond that there is no evident reason why the construction should not last indefinitely.

"Other ways of meeting the necessary conditions of design may be developed and in them the design will most certainly call for steel in combination with concrete, in such a manner that it will conform to the strict definition of reinforced concrete. The essential factors for success in any plan are workability and reasonable costs. Since unit cost of steel is high compared to concrete it is necessary that there be just enough of the metal to serve the desired purpose, and no more, in order to obtain the reasonable costs."

That is Professor Hooper's contribution. It suggests, I think, one line along which very definite progress may be made. In similar devices for an independent surface structure and on the other hand in the closer relation between roadbed and pavement we shall, I believe, follow the future course of highway design.

DISCUSSION.

Mr. Lindau. A. E. LINDAU.—Has a design been made on the precast idea; if so what quantities of material are required and the estimated cost? As I understood Mr. Breed, he proposed three supports, I presume one at each edge and one through the middle. That would divide the road then into two singly supported slabs.

Mr. Breed. H. E. BREED.—No, the idea is to have triangularly placed supports.

Mr. Lindau. MR. LINDAU.—There are then supporting pillars at the edges of the road?

Mr. Breed. MR. BREED.—Either supporting pillars or other structures that would give adequate support.

Mr. Lindau. MR. LINDAU.—What would be the size of the units in that case?

Mr. Breed. MR. BREED.—Isosceles triangles; I think in the case of a 20-ft. road, they would be about 12½ ft. spans.

Mr. Abrams. D. A. ABRAMS.—If in a soft soil we have difficulty in finding support for a full width slab, I do not understand how you would find bearing for those supports to carry a precast slab.

Mr. Breed MR. BREED.—Piles.

Mr. Beggs. G. E. BEGGS.—I would like to make one remark just about the general philosophy of breaking up what is ordinarily a continuous slab. It is an indeterminate structure, and breaking it up into a series of triangles supported on the spices we get a determinate structure that we can solve by simple mathematics. It is a poor plan to give up any type of a continuous structure every part of which is going to contribute something to supporting the load, to get a statically determinate one simply so that we can solve it and make a definite solution. I do not think that is a sufficient reason for giving up a slab and choosing that type.

Mr. Woolson. I. H. WOOLSON.—Has the author given any consideration to noise? Would not that be a noisy highway, say, passing through a village, with that space underneath? Would it not have a tendency to be noisy?

Mr. Breed. MR. BREED.—In village construction, I should think it would be just about as noisy as a brick pavement is now. This type, I think, would be more adapted to sections out in the country where you have poor subsoil and poor foundation. In most villages the pavement structure goes over the entire street and with the sidewalks you have practically an umbrella for the whole area, and your soil conditions are much better than out on the highways.

Mr. Ege. C. R. EGE.—It occurred to me in the course of the paper that the use of the term bad foundation or bad sub-soil may convey to a good many the idea of a swampy sub-soil. In observing a good many highways in all parts of the country, it has been my experience that a concrete road over a real swampy sub-soil usually gives less trouble than one over soil which changes its nature. The design suggested appeals to me as being particularly adapted to soils where the conditions change

from hard to soft grade frequently. I have in mind certain specific instances where the sub-soil is so wet and swampy that the pools of water will shake and vibrate for as much as 200 ft. on either side of the right-of-way when a truck passes over the pavement. I have gone out into such ditches and shoved down a 12 ft. flagpole just with the strength of my arm. At the same time those roads showed fewer cracks and fewer breaks than many highways where the subsoil alternates from clay to mud, and so on. It seems to me that the reason for the success of the paving slab over the all soft sub-soil may be in the equalization of the pressure. The weight of the load is more equally distributed, or perhaps I should say the reaction of the foundation underneath the slab is more uniformly distributed over the bottom of the slab. **Mr Ege.**

W. K. HATT.—Precast slabs have been used. There was a test road built in Casper, Wyo., in 1920, 2400 ft. long, under heavy traffic from the mines, using precast slabs 18 ft. long, 9 ft. wide and 6 in. thick. I think the report shows that that has carried its load with a high degree of satisfaction. There warped joints were used between the slabs, so there was no opportunity for slabs to move vertically or horizontally. They are also being used in roads in California now. **Mr. Hatt.**

An Interesting Case of Dangerous Aggregate.

By J. C. Pearson* and G. F. Loughlin.†

I.—BRIEF HISTORY OF THE CASE.

In the December, 1919, issue of Concrete an article describing rapid disintegration of a certain ornamental cast stone and stucco in the vicinity of Los Angeles, Calif., was published under the title, "A Costly Experiment with Feldspar Aggregate," by Robert B. Lammens. This article attracted considerable attention from the fact that it was interpreted as a warning

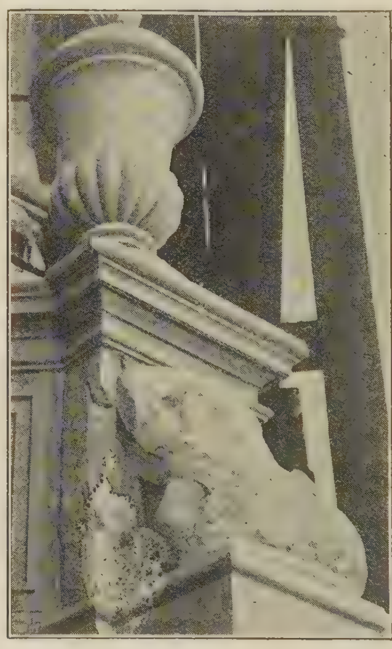

FIG. 1.—DISINTEGRATED ART STONE BASE.

against the use of feldspar aggregate, although only the lime-soda variety, plagioclase, was under consideration. It is not believed that the writer of the article intended to create exactly this impression, but rather (to use his own words) "to sound a warning against the use in concrete of rock that is not very well understood." He did, however, state the case in the following words:

*U. S. Bureau of Standards, Washington, D. C.
†U. S. Geological Survey, Washington, D. C.

"In 1913 there was put on the market here in Los Angeles an aggregate obtained by crushing a certain rock—nearly white, very hard, and of rather beautiful crystalline appearance.

"Tests on concretes made with it showed up well and the chemical analysis proved it to contain, among other things, 85% of silica. On the strength of this it was sold as 'Silica Sand,' although it has absolutely nothing in common with real silica sand.

"Art stone was being very extensively used at that time, and the new aggregate met with great favor for its manufacture. Some of the best and most beautiful stone ever made was thus produced, and possibly $150,000 worth of it was used in school buildings, churches, libraries, apartment houses, residences, etc.

FIG. 2.—DISINTEGRATED COPING OF HOUSE.

"In less than a year and a half things began to look suspicious; the rock began to decompose and the fine stone fell to pieces.

"New analyses disclosed the fact that the composition of the rock varied from sample to sample, and that, instead of silica, it was a soda-lime feldspar of the plagioclase variety."

This article naturally brought forth inquiries from users and producers of feldspar aggregate in other parts of the country, as to whether similar trouble might be generally expected from this material. The editors of CONCRETE endeavored to find a satisfactory answer to these questions and eventually requested of the Bureau of Standards general information on the suitability of feldspar as a concrete aggregate, and an explanation of the disintegration which had occurred in Los Angeles.

The Bureau felt that the matter was of considerable importance in view of the fact that both feldspar itself, and other aggregates of which feldspar is a constituent, have been widely used in the East, and so far as information was available, no question of durability or suitability of these aggregates had ever been raised. The question was immediately referred to the U. S. Geological Survey, however, and the opinion was obtained that in view of the known resistance of feldspar to ordinary weather exposures, the disintegration of the concrete was hardly to be accounted for in this manner.

The Bureau then wrote to Mr. Lammens asking his assistance in the matter to the extent of furnishing all the information available and of

FIG. 3.—DISINTEGRATED COPING OF RAILING.

supplying samples of the original quarry rock, the aggregate as used, and the disintegrated concrete. It happened that Mr. Lammens was in Europe at that time and the Bureau's letter did not reach him until late in the summer of 1920. Promptly thereafter he complied very fully with the Bureau's request, furnishing a number of samples and a complete history of the case, including an account of the physical and chemical tests that had been made prior to the marketing of the material as concrete aggregate.

Significant in Mr. Lammens' report was the fact that the preliminary tests consisted of a rough chemical analysis and the making of a few briquettes. The first sample analyzed showed 85 percent of SiO_2, on the basis of which the producers advertised the material as "Silica Sand." The physical tests, such as they were, compared favorably with those of other aggregates in common use. Mr. Lammens later had analyses of the

material made by three different chemists, all of them classifying the material as feldspar, and one of them stating that it was *altered* plagioclase or soda-lime feldspar. To the layman, and probably to the concrete engineer also, this would not mean a great deal, but to the geologist the meaning of the word "altered" is significant. The samples of aggregate submitted by Mr. Lammens were immediately identified by the U. S. Geological Survey, not as feldspar, but as a mixture of feldspar and products resulting from the decomposition of feldspar.

In the fall of 1920 Mr. Loughlin had an opportunity to investigate the matter on the ground, and called on Mr. Lammens, who showed him some of the deteriorated concrete structures in Los Angeles. He also visited one of the feldspar quarries in company with C. W. Boynton, formerly of the Universal Portland Cement Company. In the summer of 1922 he spent a day in a more extended visit to the country containing the feldspar deposit.

The concrete, seen in porches along Arlington St., Los Angeles, consisted of cast blocks with cores of concrete with sand and gravel aggregate and facings of concrete with the feldspar aggregate. The facings were in different stages of disintegration. In the first stage cracks had formed and the whole surface had begun to break away from the core. In some blocks only a thin layer had loosened; in others the entire facing about an inch thick had broken away from the core, and in the most advanced stages little or none of the facing remained. The material of the broken facings readily crumbled to sand when lightly pressed by the fingers. Much of the aggregate in it had become soft and chalky. The cores of the blocks, as far as seen, were invariably in good condition. This evidence, together with Mr. Lammens' statement that the same process of disintegration had taken place no matter what brand of cement had been used, leaves no doubt that the aggregate has been the cause of the trouble.

Figs. 1, 2 and 3, reproduced from photographs furnished by Mr. Lammens, show typical examples of the disintegrating art stone.

II.—TESTS OF MORTAR CONTAINING THE ALTERED FELDSPAR AGGREGATE.

By J. C. Pearson.

It is not always that geologists are included in the staffs of commercial and other laboratories engaged in the testing of concrete materials, and it was, therefore, important to ascertain with greater certainty whether the usual physical tests of concrete fabricated from the altered-feldspar aggregate would not have shown the unsuitability of the material. To this end a considerable amount of time and money were expended to obtain some 100 lb. of the material directly from the quarry, which could be depended upon to be truly representative of the run of the material. This shipment was received in Washington in June, 1921.

The tests were started without further delay. The rock was crushed and screened to give a similar but somewhat coarser gradation than that

of the original sample submitted by Mr. Lammens. Sieve analyses of the original sample and of the material used in the tests were as follows:

Percentage passing U. S. Standard Sieves.		
Number	Original Sample	Prepared Aggregate
8	100	100
16	100	71
30	85	50
50	46	30
100	19	14

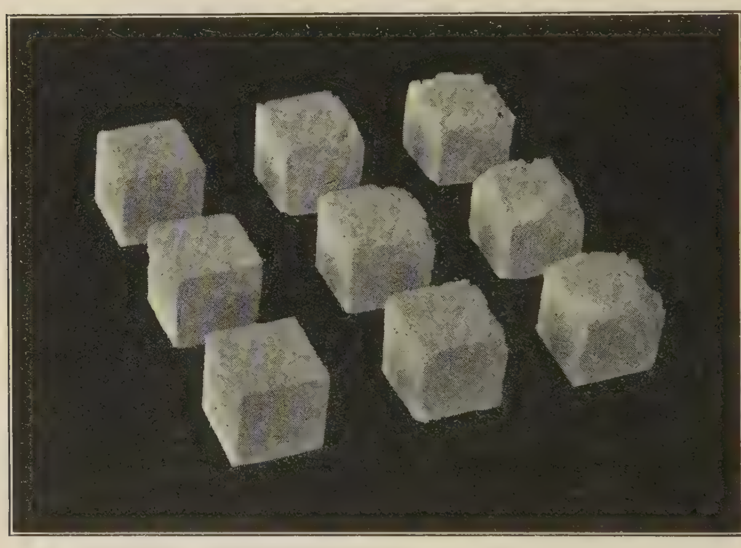

FIG. 4.—CUBES OF ALTERED FELDSPAR MORTARS AFTER 18 MONTHS' EXPOSURE TO THE WEATHER AT WASHINGTON, D. C.

Proportions of cement to aggregate as follows: Left row 1 : 2, center row 1 : 3, right row 1 : 4.

Using a normal portland cement, a number of 2 in. cubes were made up in mixtures of 1: 2, 1: 3, and 1: 4 by volume, of both medium and dry consistencies. The medium consistencies were wetter than the so-called normal mortar consistency in standard cement tests; the dry consistencies were very dry, such as to show the successive layers of mortar as tamped in the molds. It was believed that these variations would cover the range of mixtures in which the material was used commercially, but no tests were made of mixtures of other aggregates with the altered-feldspar. For comparison, similar test pieces were made with standard Ottawa sand.

The test cubes were stored in the damp closet one day, in water six days, and then removed to the roof of the laboratory where they were

continually exposed to the weather. These cubes were examined from time to time, and incipient checking of some of the altered-feldspar specimens was noted near the top edges within a few weeks. This did not become pronounced, however, until the spring of 1922. During the warm weather the action was very marked, and toward the end of the summer the edges of many of the cubes were falling away. A number of the cubes made from the dry mixes split at the junctions of the different layers where these occurred in filling the molds.

Generally speaking, the leaner mixes show more advanced disintegration than the richer mixes. The photograph, Fig. 4, taken Jan. 2, 1923, shows three typical cubes of each of the altered-feldspar mixtures after 18 months' exposure to the weather. The disintegration of these specimens seems to be in all respects similar to that of the concrete stone which occurred in Southern California. It may be noted in passing that no signs of disintegration have been observed on the standard Ottawa sand specimens.

The compression tests of the cubes, which to date have been made at the 7-day, 28-day, 3-month, and 1-year periods are particularly interesting, not only because they would have given the altered-feldspar aggregate a clean bill of health at the usual 28-day period, but also because the strengths have held up remarkably in spite of visible disintegration. The results of the compression tests reported in the following table are the averages from three specimens:

Compression Strength, lb. per sq. in. 12 in. cubes.

Aggregate	Mix	Percent water	7-day (water)	28-day (water)	28-day (air)	3-month (air)	1-year (air)
Medium Consistency.							
Feldspar	1:2	17.4	2320	4040	3890	4390	5490
Std. Sd.	1:2	11.8	3090	4390	4790	5290	6570
Feldspar	1:3	17.4	1310	2420	2400	2590	2860
Std. Sd.	1:3	13.1	1020	1800	1900	2030	3170
Feldspar	1:4	17.2	820	1460	1430	1700	1680
Std. Sd.	1:4	13.4	630	1020	1230	1430	2280
Dry Consistency.							
Feldspar	1:2	12.5	3080	....	5010	4970	6080(a)
Std. Sd.	1:2	8.0	3980	....	6810	6020	6920(a)
Feldspar	1:3	12.5	2840	....	4570	4410	4150(a)
Std. Sd.	1:3	7.1	1600	....	3610	3940	4430(a)
Feldspar	1:4	12.0	1820	....	3500	2920	3020(a)
Std. Sd.	1:4	7.0	1250	....	3490	3600	3540

(a) These specimens were broken at 14 months.

The results in the foregoing table are shown graphically in Figs. 5 and 6.

The strength-age curves from the very dry mixes are somewhat erratic, as might be expected, but they show the same general ten-

dencies as those from the medium mixes, which exhibit the following characteristics:

(a) The altered-feldspar aggregate gives higher strengths than the standard Ottawa sand in the leaner mixes up to and including the 3-month

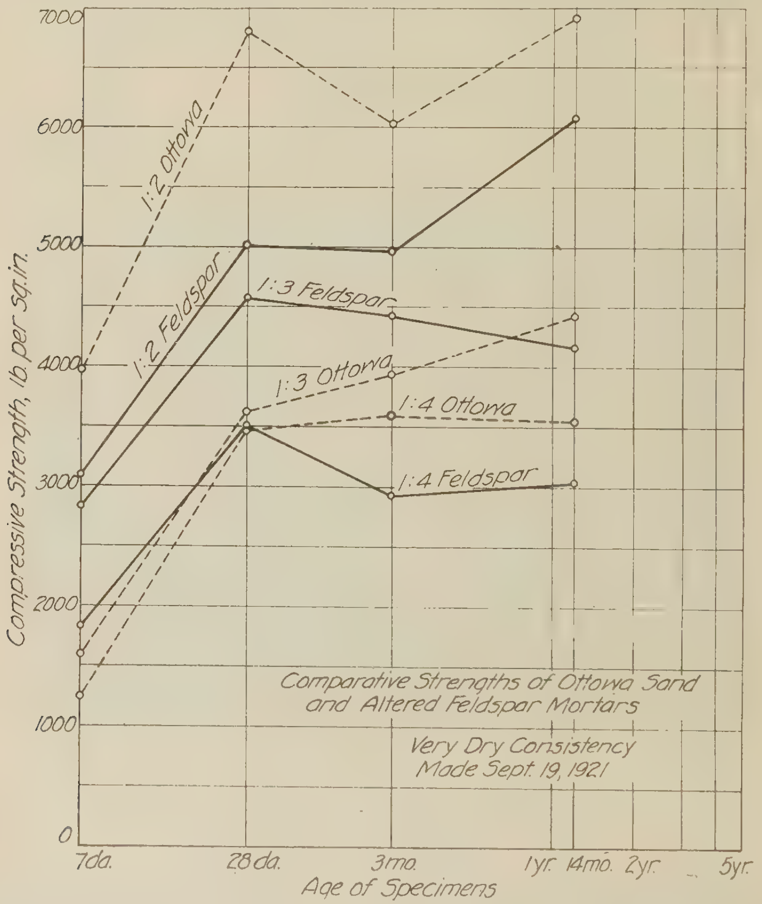

FIG. 5.—COMPARATIVE STRENGTHS OF OTTAWA SAND AND ALTERED FELDSPAR MORTARS. (VERY DRY.)

period. This is unquestionably an effect of the gradation of aggregate, and would have been exhibited by any normal aggregate of similar gradation. In the 1 : 2 mixes the effect of the excess fine material in the altered-feldspar aggregate is to give lower strengths than the standard sand.

(b) The destructive effect of the altered-feldspar aggregate is becoming apparent in the 1 year tests, when the strength of the leaner mixes falls below that of the standard sand specimens. In the 1 : 2 mixes there

is no appreciable falling off in strength of the altered-feldspar specimens up to 1 year.

(c) Visible and apparently considerable disintegration occurs before the strength of the altered-feldspar specimens is appreciably affected. This

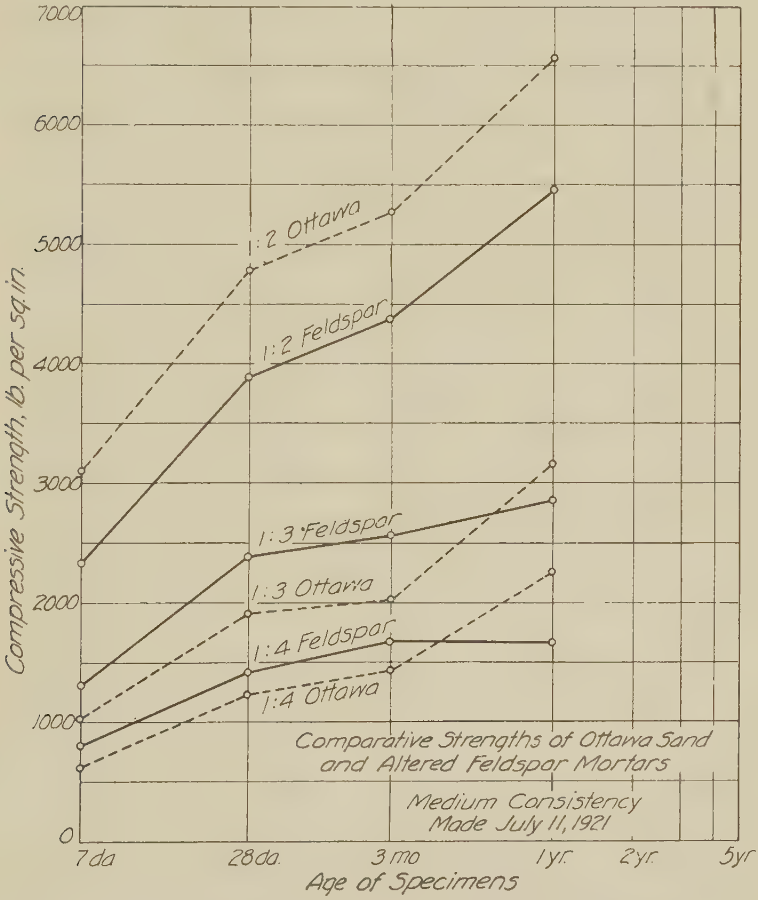

FIG. 6.—COMPARATIVE STRENGTHS OF OTTAWA SAND AND ALTERED FELDSPAR MORTARS. (MEDIUM CONSISTENCY.)

indicates that the deterioration starts at the surface and progresses slowly inward.

It is worth while to remark that the laboratory tests serve to show the increase in strength of the cement in newly formed cōncrete, but have no significance regarding the durability of the aggregate. The aggregate used disintegrates more slowly than cement hardens, but still is very rapid if measured in terms of the life of a building.

III.—THE ALTERED-FELDSPAR AND CAUSES OF ITS DISINTEGRATION.

By G. F. LOUGHLIN.

The feldspar, as stated by Mr. Lammens, is the lime-soda variety called Labadorite and occurs as the principal constituent of a large mass of rock technically known as anorthosite. This formation is exposed in Soledad Canyon, about 50 miles north of Los Angeles, and has been traced from a point three-quarters of a mile east of Lang Station for about 8 miles eastward to Ravenna. On the north side of the Canyon it is overlain by a thick deposit of gravel, sand and clay, more or less consolidated, the lower beds of which (all that were seen) consist mainly of pebbles or cobbles of the anorthosite. Near Lang these beds cover the anorthosite on both sides of the canyon. The anorthosite, which varies locally from white rock consisting almost entirely of the altered-feldspar and bluish-gray rock of unaltered-feldspar to rock containing considerable quantities of dark colored minerals, forms the south slope of the canyon and extends southward for an indefinite distance. It is cut out here and there by small veins or dikes of coarse grained granite (pegmatite), and a mile and a half west of Ravenna both it and the overlying gravel are cut by a large dike of decomposed trap rock. It is one of the very few occurrences of anorthosite of appreciable size in North America. By far the largest occurrences occupy extensive areas in eastern Canada and the Adirondack Mountains of New York. I found another occurrence of appreciable, though comparatively small, size in northern Idaho in 1910, and the occurrence in Soledad Canyon is the only other of appreciable size of which I have heard.

The altered-feldspar rock, or white anorthosite, was quarried for a short time at Alpine switch, 2½ miles east of Lang and also somewhere near Ravenna; but when its defective qualities became generally realized about 1913, the quarries were abandoned. Only the quarry at Alpine was visited. This quarry, from which the material used in the tests at the Bureau of Standards was collected by Mr. Boynton subsequent to our visit in 1920, is close by the railroad. It is a side hill quarry and the quarry face about 100 ft. long, is close by a railroad siding.

The rock at and near the quarry is white to pale pink as a whole, but contains several slabs like inclusions of weathered dark rock, mica schists and hornblende. It is thoroughly shattered and along many of its fractures slight displacement or faulting has taken place. It is considerably altered these fractures, though cores of practically unaltered rock remain in the central parts of irregular blocks.

Inspection of these cores shows them to consist essentially of coarsely granular, but thoroughly welded dark purplish or smoky feldspar—a feature characteristic of fresh lime-soda feldspar in anorthosite and related rocks. A small quantity of black mica is present and is considerably

rusted by weathering. Where the black mica is unusually abundant and in relatively large flakes, it promotes weathering on prolonged exposure, but has nothing to do with the kind of weathering that took place in the concrete. Specimens of this unaltered material are most readily obtained from cobbles in the creek bed along the canyon bottom where abrasion has removed the soft altered material. Under the microscope even this material shows the effects of crushing and recrystallization, also of deep-seated alteration which has developed the secondary minerals epidote (hydrous silicate of lime, iron, and aluminum), calcite (calcium carbonate) and white mica (hydrous silicate of potassium and aluminum). These minerals form scattered grains, most of the white mica grains lying along cleavage turning and shearing planes. The calcite also forms veinlets. Where they are abundant the original dark color of the feldspar is lost, but the material is still resistant to weathering. The dark color is also destroyed by recrystallization which has resolved original large feldspar crystals into relatively fine grained aggregates. The black mica proves to be mostly altered to the green micaceous mineral chlorite accompanied by a minor amount of white mica. The titanium—iron oxide, ilmenite, in a few small grains—is the only other conspicuous microscopic mineral.

In the chalky white to pale pink material surrounding the cores, the original texture of the rock is also lost. Where it has been exposed for some time the rock cracks into smaller and smaller fragments. Although described to me as a hard rock, it offers little resistance to the hammer and in this respect also is in marked contrast to the unweathered core. The chalky white material is partly present in distinct veinlets which range in thickness from ⅛ in. down to sub-microscopic dimensions. Under the microscope these veinlets form a fine network and consist of the zeolite, laumontite, accompanied in places by a little calcite. The minute feldspar fragments within the network are largely altered to a mixture of the zeolite and kaolin.

The abundance of these veinlets varies. In the rock that has lost its original dark color but retains its texture and the lustrous cleavage surfaces of feldspar a few veinlets may be present, and all gradations from such rock to rock entirely altered to a mixture of the zeolite, kaolin, and calcite in varying proportions may be expected. One specimen of a small grab sample collected from the quarry face consists mainly of calcite.

Cause of Disintegration.—The three minerals responsible for the disintegration are laumontite, kaolin, and to a very minor degree calcite. The fact that aggregates of limestone and marble which consist essentially of calcite in concrete have given general satisfaction is sufficient evidence that calcite alone is not responsible for rapid weathering. One specimen of altered rock which the microscope showed to consist mainly of calcite, resisted weathering tests better than altered rock that contained very little calcite. But finely crushed grains of calcite mingled with the other two minreals are subjected to an unusually severe test and have decomposed, whereas a similarly fine aggregate of quartz or of unaltered feldspar would not have been appreciably affected.

The kaolin when exposed to the weather tends to absorb water which causes swelling and cracking and finally complete slaking. Specimens of thoroughly altered rock, however, when immersed in water did not slake, and alternate soaking for 24 hours followed by drying in the sun for 24 hours and continued for two months failed to produce any disintegration other than a very slight crumbling along the surfaces. The same specimens after being exposed to the summer sun but not to moisture for two months disintegrated almost completely. The primary cause for disintegration was the decomposition of the laumontite through loss of water. After this decomposition has started disintegration of the rock, the slaking properties of kaolin, the fine particles of which have become more exposed to the atmosphere, may aid in making disintegration complete.

Laumontite is a hydrous silicate of calcium and aluminum. Its chemical formula, according to Dana's (Textbook System) of Mineralogy (p. 457), is $CaAl_2\ Si_4O_{12} + 4\ H_2O$. Its tendency to lose its chemically combined water, however, is very marked and chemical analyses as well as records of its optical properties vary accordingly.

Microscopic examination of sound and unsound concrete showed that the feldspar aggregate in the sound concrete is mostly free from conspicuous alteration. Some fragments contain prominent veins of epidote and white mica. A very few are heavily sprinkled with very fine grained aggregate of the same minerals and perhaps with a very little of laumontite and kaloin, too small to be recognized. Some grains contain considerable calcite. The presence of several fine scales of white mica in the cement matrix suggests insufficient washing of the aggregate before use. Failure to wash ground unaltered feldspar may not be serious, but failure to wash the thoroughly altered rock would leave an abundance of the soft laumontite and kaolin dust to mingle with the cement matrix and create a tendency to rapid disintegration.

In one thin section of unsound concrete nearly all the feldspar grains are thoroughly altered to a fine aggregate of zeolite, kaolin, calcite, and white mica. This concrete was so fragile that the thin section for microscopic study was much broken during preparation. The breaks were all in the cement matrix, which is darker than that in the sound concrete, due perhaps to the presence of considerable dust, which may have decreased the strength of the cement. In another thin section of unsound concrete the feldspar was less extremely though considerably altered, and several fragments of aggregate had been torn out of the matrix during grinding, suggesting that the strength of the matrix was satisfactory, but that some of the grains were too much decomposed to resist grinding.

These microscopic differences together with the presence of relatively unaltered cores of rock in the quarry account for the fact that the facings of some concrete blocks have disintegrated, whereas others close by have remained nearly or quite intact. Unless care had been taken to mix thoroughly the finely ground aggregate only such irregular results could be expected.

Conclusion.—This occurrence, so far as I know, is unique in the history of concrete. The fact that this altered feldspar weathers so rapidly should not be regarded as an indication that feldspar, whether the potash-soda varieties (orthoclase and microcline) or the soda and lime-soda varieties (labite, obgoclase, andesine, labradorite, bytownite, and anorthite) is undesirable as concrete aggregate. Stone consisting largely of one or more of these feldspars have resisted weathering for many years in buildings and other structures, and their feldspar constituents show little or no evidence of disintegration. Where slight alteration is evident the feldspar contained considerable finely divided calcite, white mica, and kaolin, all of which are subject to slow chemical or mechanical weathering; but these minerals were developed by alteration long before the stone was quarried, and the effects of weathering simply indicate that the stone was poorly selected. Fresh or only slightly altered feldspar is not subject to rapid weathering.[1]

The real lesson taught by this experience is the necessity of making sure that any unusual or hitherto untried material is suitable for aggregate before putting it to such use. Any tests made should be of the material itself before tests of concrete containing it are begun. It would be ridiculous to assert that all materials for aggregates should be thoroughly studied and tested before being used, but where any doubt arises the time and money lost in having the material properly examined at first may save a vastly greater amount of time, money, and trouble later.

IV.—SUMMARY.

The most important results of this investigation may be summarized as follows:

The failure of the artificial stone in Los Angeles was due to the use of unsuitable aggregate, an altered lime-soda feldspar. Concrete made of this aggregate and exposed in Washington, D. C., has shown the same type of failure within a comparatively short period of time.

Test specimens made up and tested in the manner usually prescribed for tests of aggregates did not indicate the unstable nature of the altered-feldspar aggregate. Long before the strength of the specimens was appreciably affected, disintegration was apparent from visual inspection. Attention is called particularly to the fact that strength tests alone are not sufficient to indicate the durability or acceptability of an aggregate.

It has been shown that the altered-feldspar (plagioclase) contained a large quantity of the zeolite, laumontite, which was primarily responsible for the disintegration; also kaolin, which tended to hasten the process of disintegration after it had started; also calcite, which, though relatively

[1] An apparent exception is the "blistering" or scaling of granite; but this is primarily due not to the stone but to too severe hammering during the dressing of the stone. Granites with unusually large scales of mica or with an abundance of mica are more likely to suffer from this abuse, and pronounced alteration of their feldspars would render them still more so.

stable, tends to decompose rapidly when finely divided and in contact with water. Other alteration products were present, but had nothing to do with the rapid disintegration. Residual cores of partially unaltered feldspar among the altered material have resisted weathering, and add to the evidence in general that lime-soda feldspar (plagioclase), if free from serious alteration when quarried, is not subject to appreciable weathering under ordinary conditions of use. The same statement may be applied to the potash-soda feldspar (orthoclase or microcline).

There is nothing in this case, therefore, to give rise to question regarding the permanency of feldspar aggregate as such. Feldspar aggregate free from serious alteration when quarried will, under any conditions, undoubtedly outlast any cement matrix which binds it together in the form of concrete.

DISCUSSION.

D. A. Abrams.—Have the speakers any recommendation as to methods which might be used in case of an aggregate of this kind or other unknown aggregates, as to methods of determining their suitableness for concrete aggregates within the ordinary period of 28 days? Mr. Abrams.

G. F. Loughlin.—If you turn the sample in to a mineralogist or petrographer, he ought to be able to have a microscopic section prepared in a short time and make a few qualitative chemical tests for certain minerals that are bound to be unsatisfactory in resisting the weather, and report the results. There are a few minerals that are notoriously bad, but others that may be comparatively unusual, that you may not think of, and then it would be up to the petrographer to express his opinion and postpone the use of the material in case of doubt, postpone the use of the material, but find out experimentally and see. Mr. Loughlin.

Mr. Abrams.—I would like to ask why this investigation would not work out in the case of shale, shalesand, shale gravel? We know from experience that many types of shale are not suitable, and I know it has not been determined just how far down in the shale you can go and be justified in rejecting the material. Mr. Abrams.

Mr. Loughlin.—There are other gradations of shale, from that which is practically slate through the typical shale, to consolidated clay. It is the capacity of the clay for absorbing water that is the cause of this graphic disintegration. It might be that a mineral like gypsum, which will dissolve in the weather rapidly, may also be present, but that is uncommon, and where the particles can be found with the ordinary microscope; still a qualitative test of the questionable particles seen through the microscope ought to throw some light on it. Mr. Loughlin.

METHODS OF ESTIMATING THE COST OF CONCRETE WORK.

By Frank R. Walker.*

It is impossible to prepare an estimate on concrete work without first having a method of measurement, and after the quantities have been prepared, it is necessary to have unit costs compiled in the same manner in which the quantities have been listed, if we expect to have a semblance of accuracy in our estimates.

It is altogether likely that if ten contractors, selected at random (not all large contractors nor all small ones but a fair representation of both), were asked to describe the methods used by their organization in estimating the cost of concrete work, the possibilities are that we would have from seven to ten different methods to consider. It seems that each contractor has developed his own method of estimating or has followed the path of least resistance that has enabled him to "get by," but with no valid reason for using that method, except, perhaps, that it was quick—but the same could not be said of its accuracy.

If estimates are to be accurate, so that the contractor will feel safe in taking work on his own figures, the various branches of work should be estimated in exactly the same manner in which it is erected in place in the structure, using each completed operation as the basis of measurement and pricing the work—but regardless of the method used in preparing the estimate, if the contractor's field organization is incompetent or inefficient, the best prepared estimate will not make the contractor's business a profitable one.

Each class of concrete work should be estimated separately, such as footings and foundation walls, column footings, retaining walls, reinforced-concrete columns, beams and girders, stairs, structural floor slabs, etc., because each is a separate and distinct class of work, involving special details of construction not found in the others, and subject to considerable variation in the cost of the completed units.

When estimating the cost of concrete for foundations and retaining walls, the cost of the wood or metal forms, reinforcing steel, and the cost of the concrete itself should each be estimated separately, as they are all separate kinds of work and in many instances installed by different trades.

The concrete itself should be estimated by the cubic foot or cubic yard, but personally I prefer the cubic yard method because the costs are more easily worked out on that basis. Nearly all tables of cement, sand, gravel or crushed stone are stated in the quantities required per cubic yard of concrete, which makes a more workable unit than where the cubic foot method is used.

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Formwork.—Formwork should always be estimated by the number of square feet of forms required for any given piece of work; for instance, if a wall is 60 ft. long and 8 ft. high and requires forms on both sides of the wall, it will require 960 sq. ft. of forms for the wall. In figuring formwork by the square foot, I think it is also advisable to consider the quantity of lumber required to construct one square foot of forms. Light walls will require only 2 or 2½ ft. of lumber, b. m., to construct one square foot of forms complete, while heavy retaining walls will require 3½ to 4 ft. of lumber, b. m., per square foot of forms. Naturally the more lumber required per square foot of forms, the higher the material and labor costs will be.

It is not a difficult matter to strike an average of the amount of lumber required to construct one square foot of forms for various types of walls, and by so doing it furnishes valuable costs both by the square foot of forms and per thousand feet of lumber, b. m. This is especially valuable when comparing costs on various jobs. The cost of removing the forms should also be kept separate from the cost of framing and erecting, but the same units of measurement should be used throughout.

Reinforcing steel should be estimated by the pound or ton, estimating the cost of steel at a certain price. The labor bending the steel should be kept separate from the cost of placing the steel in the structure ready to receive concrete.

When estimating the quantities and costs of reinforced-concrete superstructures, each class of work should be estimated separately as previously described for foundations and retaining walls, but the average concrete building contains at least four different classes of reinforced work, namely: columns, beams and girders, floors and stairs.

Column Forms.—The forms for square concrete columns should be estimated by the square foot, taking the entire girth of the column and multiplying by the height. As an example, take a column 18 in. square and 12 ft. high. Forms will be required on all four sides of the column, making a total girth of 72 in. or 6 ft., which, multiplied by the height, will give 72 sq. ft. of forms required for each column. Where 2-in. lumber is used, it ordinarily requires about 2½ ft. of lumber, b. m., to construct one square foot of forms, including bracing, clamps, etc. In order to prepare accurate estimates on the cost of this work, it is advisable to estimate the cost of framing and erecting the column forms, separate from the labor cost of removing them after the concrete has been placed. The same units of measurement should be used in both instances.

The forming for octagonal concrete columns presents a somewhat different problem in estimating. Regardless of the diameter of the column, there are eight different sections to be formed, and it does not cost any more to frame an 8-inch section than a 6-inch one, so it is a question whether it is not advisable to estimate the labor cost at a certain price per column, making a slight allowance for the difference in size. However, regardless of the diameter of the column, the labor cost of framing and

erecting the forms in place should be kept separate from the labor cost of removing the forms after the concrete has been placed.

Metal molds are ordinarily used for forming round concrete columns. The column molds are fabricated in the shop and delivered to the job in sections, so that a certain price should be allowed for the erection and removal of each column mold, stating the diameter and height of the column, and whether a plain shaft or one having a flared head, as the latter cost considerably more to erect than the former. The cost of the erection of the forms should be kept separate from the removal of same, if possible.

The column reinforcing steel should be estimated by the pound or ton. Inasmuch as the spirals are usually furnished fabricated and the steel cut to length, the labor estimate should include assembling, wiring and placing, based on the actual weight of the steel used.

The concrete in the columns should be estimated by the cubic foot or cubic yard; the materials being estimated according to the proportions of cement, sand and gravel used, and the labor costs of mixing and placing same, should be estimated separately.

Beam Forms.—There is a diversity of opinion among contractors regarding the correct method of estimating forms for concrete beams, girders and lintels. When used in connection with concrete floor slabs, the depth of the beam or girder ordinarily includes the thickness or depth of the slab, so when estimating the quantities and cost of beam and girder forms, I feel the proper method is to take that portion of the beam or girder that is exposed beneath the slab, while some contractors estimate forms for the full depth of the beam. For instance, if a concrete beam is 16 x 24 in. in size, and the thickness of the slab is 6 in., the actual depth of that portion of the beam requiring forms is 18 in., the other 6 in. being made up in the thickness of the concrete floor slab. Where beams and girders are used around stair well openings, elevator shafts, door and window lintels, etc., where one side of the beam is exposed for the full depth, then the girth of the beam would be 18 in., plus 16 in., plus 24 in., or a total of 58 in.

Beams may be constructed of either 1 or 2-in. lumber or a combination of the two, but the labor cost per square foot remains practically the same in either instance. The 1-in. lumber is somewhat easier to frame, but it requires more bracing than the 2-in. lumber, so that the advantages of one practically offset the other. While the estimated labor costs should be by the square foot of forms actually constructed, the labor cost of framing and erecting the forms should be kept separate from the labor cost of placing the steel in the forms ready to receive the concrete.

The reinforcing steel should be estimated by the pound or ton, based on the actual amount of steel required. Bending and fabricating should be kept separate from the labor cost of placing the steel in the forms ready to receive the concrete.

There are so many types of reinforced-concrete floors being used today

that it is almost necessary to use a different method when estimating each type. It is true, the square foot method of measuring the forms can be used in all of them, but there are so many special conditions entering into the construction of the forms for the various types of floors, that each must be given careful consideration when preparing the estimate. The amount of lumber required to construct one square foot of forms for reinforced-concrete floors will vary from about 2¼ to 4½ ft., b. m., which includes sheathing, joists, stringers, uprights, sills, wedges, bracing, etc. This variation is due to the thickness of the concrete floor and the height of the ceiling. For this reason, it is well to check the square foot method with the price per thousand feet of lumber, b. m., before pricing the estimate.

It is not necessary to figure out the exact quantity of lumber required in the construction of the slab forms for each job estimated, but a table can be easily prepared showing the approximate amount of lumber required to construct one square foot of forms for different slab thickness and varying ceiling heights. This will be close enough for estimating purposes, because I have never yet seen the job where the quantity of lumber used was the same as the quantity estimated.

Floor Construction.—Before deciding upon the material cost per square foot of forms, it is advisable to take into consideration the number of times each floor of forms may be used in the construction of the job. For instance, if it requires 3 ft. of lumber, b. m., to construct one square foot of forms, with lumber at 5 c. per ft., b. m., the lumber cost of one square foot of forms would be 15 cents. If the lumber may be used two or three times in the construction of the job, this cost may be divided by two or three to obtain the lumber cost per square foot of forms. To this cost a small allowance should be added for breakage, waste, nails, etc.

Where solid concrete floors are used in connection with beams and girders (either of reinforced-concrete or structural steel, fireproofed with concrete), the exact floor area between beams and girders should be obtained, and should not include the width of the beams and girders, as these forms have previously been taken care of under beams and girders, and all duplication of quantities should be avoided, if accurate estimates are to be obtained.

The same method should be used when estimating floors of flat slab construction, except that the area of the depressions at the column heads should be taken off separately, as there is considerable extra labor involved in framing out for these depressions. The entire area of the floor may be estimated at a certain price per square foot, and then an additional allowance may be made to take care of the additional labor required for framing for depressions in slabs.

Other types of floor construction, where concrete is used in conjunction with clay or gypsum tile, metal tile, "domes" or tin pans, as they are commonly called, usually require the lightest type of temporary framing for forms on account of the small weight of the floor slab itself.

In all instances the exact floor area should be obtained and the work priced by the square foot of forms. On work of this kind, some contractors cover the entire floor with wood sheathing while others place only a 2 x 6 or 2 x 8-in. plank, 12, 16 or 20 in. on centers, to support the ends of the tile or domes and form the bottom or soffit for the concrete joist which is to be placed.

It is certainly advisable to keep separate costs on the various types of floor construction both by the square foot of forms and by the thousand feet of lumber, board measure, as this helps materially in preparing more accurate estimates, permitting a comparison of costs by both methods.

I recently read an article on estimating concrete work, which stated among other things that all lumber used in concrete forms could be estimated at about $16 per thousand for erection and $4 for removing the forms after the work was in place. The man who wrote that evidently never kept any accurate costs on his work.

The actual concrete on all of the various types of floors should be estimated by the cubic foot or cubic yard, but there is a vast difference in the labor cost of placing concrete on a job having 10 or 12 in. floor slabs than those using clay tile or metal domes, having concrete joists 4 or 5 in. wide with only 2 or 2½in. of concrete placed over the top of the tile themselves. The former will require four or five times as much concrete per square foot of floor as the latter.

On heavy slabs it is possible to place a large amount of concrete in a comparatively small floor area, while with the combination types of floor, it is necessary to cover a large floor area and place only a comparatively small amount of concrete. Floors of this type require considerable extra labor placing the concrete in small joists, using care to see that all reinforcing steel is covered, as well as extra labor in spreading and grading the concrete for the thin top slab. While the cubic foot or cubic yard method of measurement may be used for either type floor, the labor cost on one will be much higher than on the other.

Where the floors are to have a cement finish top, the top should be estimated separately in all instances. The thickness of the top may vary from one-half to three-quarters of an inch in thickness and is composed of cement and sand, an entirely different aggregate than the mass concrete. This will involve separate material and labor costs, such as cement finishers and helpers, placing, screeding and troweling the top, which is in addition to the labor required placing the structural concrete. Measurement of work of this kind should be by the square foot.

Stairs.—Nearly every contractor has his own method of estimating concrete stairs. Many take the underneath surface or soffit of the stairs to obtain the forms required, while others take the area of the soffit plus the number of lineal feet of risers. It is a difficult proposition and one that is not easily checked.

I have used the following method of estimating concrete stairs for a number of years and it has worked out very well.

I first take the length of the stringers of each flight of stairs, making a note of the number of treads in each. According to my experience on the job, the most time is required in laying out the stairs, cutting the stringers and placing them ready to receive the sheathing and risers. I usually allow a certain number of hours carpenter time to lay out, cut and erect the stringers. I then estimate the sheathing in the same manner as is used in estimating slab forms, making my allowance in the price. I then mention the number of treads and the length of same, together with the number and length of the risers to be placed. In making up my estimate in this manner, I have found my estimated and actual costs compared very favorably.

The concrete is estimated in the usual manner to obtain the number of cubic feet or yards of concrete to place.

If the stairs are to have a cement finish, I usually allow 18 in. to take care of the width of each tread and riser and multiply this by the length of the treads and the number of same to obtain the number of square feet of finish.

Miscellaneous Items.—When estimating the quantities of mesh or fabric reinforcing, I think the actual area of the surface to be covered should be obtained and then a certain allowance made to take care of the laps, the same as is used when figuring wood sheathing or flooring.

In my opinion, the item of plant and equipment should be estimated separately, allowing a certain price for concrete mixers, hoisting engines, hoisting towers, and other equipment, as in many instances this cost would be the same whether the job contained 1,000 or 5,000 cu. yd. of concrete, so that if this is estimated separately, it is much easier to obtain costs from the work that are authentic and of value when preparing future estimates.

If the estimated quantities on all classes of work are as near as possible to the actual quantities that are to be placed in the job and if costs are kept in the same manner, the contractor should be able to compile costs that will prove invaluable to him when preparing estimates on future work.

Methods of Measurement.

By J. W. Ginder.*

There are probably few undertakings of the magnitude of the building business in which there can be found a greater waste. One of the sources of waste is the lack of definite methods of cost keeping, and no system of value can be established without standard rules of measurements.

The cost of building vitally influences the economic life of every man and woman. It forms the basis for rents of the home, which enters directly into the cost of living of the family or it forms one of the elements that goes to make up the overhead in a commercial or manufacturing enterprise and thereby adds to the cost of the necessities of life. When methods of construction were simple and wages were low, any one's guess as to the price to be fixed for a piece of work was as good as another. Today the situation is different.

Because of high wages and intricate methods of construction, correct costs cannot be determined nor reliable estimates made unless quantities are taken off correctly and intelligently described. Such information can only become available by making a careful quantity survey.

In the invitation, which I received, to take part in the discussion of the cost of concrete work, it was suggested that the subject seems to naturally divide itself into three heads:

(1) Methods of measurement of concrete work,

(2) Methods of recording concrete work,

(3) Methods of estimating concrete work.

Measuring Concrete Work.

Mention was made of the fact that the methods of measurements used in unit priced contracts differ from those used in contractors' offices. I am not advised to what extent the unit price is used as a basis for contract nor what demand there is for rules of measurement for that purpose; but there can be no question that there should be a differentiation between the rules of measurement to be used in determining the cost of production and the rules of measurement to be used as a basis of purchase of the finished product. There might be added another heading something like "Methods of measurement for paying for concrete."

There is a considerable difference between the measurements that are necessary in order that an actual scientific analysis may be made of the costs—or the price fixed representing the cost of executing the work—and the measurements that would be employed as a basis for unit price contracts. It is first necessary for the bidder to determine what the actual costs of the work will be, to which he will add his overhead and his profit, and then this price would be translated into a price per unit upon which to base a contract.

Inasmuch as most of the contracts are obtained from competitive

*Office of Supervising Architect, Treasury Department, Washington, D. C.

bidding, either for lump-sum or by the unit price contract, it is believed that there should be first laid down definite standard rules of measurements for taking off quantities.

Before a contractor is in a position to give consideration to the making of a price which can be used as the basis of a contract it is necessary that measurements be made that will permit the determining of the quantities of the several kinds of materials, and the cost of all the separate acts of labor: such as the amount of cement, sand and aggregate; mixing the concrete; carrying it to the place it is to be used; placing and tamping it, etc., the cost of cutting, bending, placing and securing the reinforcement; the cost of materials for the forms; the making, placing, stripping, remaking, resetting, together with the depreciation, and salvage value.

If definite standard rules of measurements are established by which the amount of material and labor can be very closely determined it is not so material whether there be standard rules of measurement, as the basis of unit price contract. The contractor can easily translate his price into any unit basis for which the invitation may call.

METHODS OF RECORDING.

Before dependable estimates can be made for submission in competitive bidding, a uniform cost keeping system is necessary and before this can be established standard rules of measurement should be adopted, such rules should require measurements be made in such a manner as to permit determining the quantity of all the materials and the amount of labor necessary for the proper execution of each kind of work.

This would require that concrete of different kinds and concrete in different positions be taken off separately. It costs more to get the concrete or the materials to the top of a 20-story building than to the first floor, or to place concrete in a reinforced floor than in a heavy wall. The amount of labor required to place reinforcing steel is more in some places than in others.

All voids or openings should be deducted. If there is extra cost in connection with forms in the finishing of the concrete on account of the voids or openings, such extra labor should be taken off and fully described. In no case should one be left to off-set the other. Such practice might result in loss to the contractor.

If the corners of beams of columns are chamfered, it should be so noted. The chamfers may have little effect on the quantity of concrete required, but they must be considered in connection with the quantity of materials and labor in connection with forms, and especially if the surface of the concrete is to be treated after the forms are removed.

A complete bill of quantities of all lumber required for forms should be made, keeping that for forms of a different character or in a different position separately.

Sketches or drawings of a type of forms intended to be used should be made for this purpose as well as for use in case the work is carried out.

The rules now included in the recommendations of this Institute* were prepared for the purpose of forming a basis for unit price contracts. Some of these rules could well be followed by contractors for measurements to determine the cost of concrete work, while others probably should be eliminated. I shall now consider these rules in detail from the point of view of obtaining the necessary information for a contractor to estimate the cost of the work.

A. C. I. MEASUREMENT RULES.

For the purpose of making a quantity survey, Rule 2 might be omitted.

Rule 9. While the concrete should be measured by the cubic foot, surface finishes, nosings, returns at ends, etc., should be taken separately.

Rule 10. In making a quantity survey for forms, decide upon the type of forms that is to be used, then a complete bill of all the different materials should be taken off. In determining the cost of forms consideration must be given to the quantity of the materials and the amount of labor required to construct and place them. A separate item should be made for each time the forms are to be taken down, or re-set. Also consideration should be given to the waste that would occur in connection with re-using the forms, and also the final salvage value.

Rules 11, 12, 13 and 14 should be eliminated.

Rule 16. Angle fillets or bevels to beams, columns, etc., are elements of cost, especially in connection with labor and due note of same should be made.

Rule 17. Openings should receive due consideration. While there may be no deduction to be made for materials, there may be an added cost on account of additional labor.

Rules 20, 21, 24. If consideration is given to the actual materials used and labor performed upon the forms, these rules should be omitted inasmuch as the data from which to obtain the cost would be taken care of under the general rule for the taking off of material.

Rule 27. In addition to the linear foot measurement, the girth of moldings should be given, or better still a sketch indicating the character of same with dimensions indicated.

Rule 32. The section of window sills, copings, etc., should be given, and dimensions indicated.

Rules 33 and 34, could be omitted, they being covered by the general rule for taking off materials for forms.

Rule 34 (a) and (b) might be retained.

Rule 37 should be changed so that the actual weight required to be purchased rather than the net weight placed in position would be given, and each kind should be kept separate.

Rules 40, 41 and 42. Allowances should be made for cutting, waste, different positions, locations, and purpose of reinforcing, and due note should be made of the number of spacers, quantity of wire ties, etc.

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*Proceedings, Am. Conc. Inst., Vol. 8, 1912.

Rule 45. Sketches showing the character of bending should be given.

Rule 47. Allowance should be made for waste, cutting, etc., as well as for laps, and due consideration should be given to the quantity of material that would be required to be purchased rather than the actual measurements of the material after it is placed.

Rule 49. It would not be necessary to give consideration to the surface of concrete after the removal of forms where no special treatment is required, but wherever any such surface is to be treated in a manner that would require any additional labor, such surface should be measured and the character of the labor required indicated.

Rule 50. Granolithic as used in this rule and also in Rule 55, is one of a number of terms that was formerly used to describe different kinds of finish containing granite aggregate, which it is understood, was at one time patented. Another being granitoid. Would it not be just as well to substitute the word "cement" for granolithic.

Rule 52. Inasmuch as some concrete work may require protection and others may not, and that it is an element of cost depending upon the character of the finish, it should be specifically stated whether or not protection is to be required, and if any particular kind is desired it should be so noted.

Rule 53. The section with dimensions, as well as description of finish should be given.

Rules 63 and 64, should be omitted.

Rule 66. It is not sufficient to employ only the weight as the unit to determine the cost of setting structural concrete. There might be a number of pieces that could be easily set by hand, while there might be many other pieces that might require the use of derricks and several men. Also the location or height to which the materials are to be raised would influence the cost. Therefore, it would be necessary to make such notations of these conditions as would enable the person who fixes the price to determine what the cost should be.

Rule 70. Unless the concrete is to be cast in permanent forms, consideration should be given to the cost of making the forms and in such a case, methods similar to those required for forms for other work should be used.

Rules 71 and 72. If reinforcement is employed it should be taken into account in similar manner to that employed with other concrete; likewise surface finish wherever the same is treated after removal from the molds should be given consideration.

Assuming that standard rules of measurement for unit price contracts should be made, it is believed that they could be reduced in number.

For mass concrete, such as walls, or even reinforced floors, the unit of measurement for the basis of a contract should provide for the concrete by the cubic foot; for the steel by weight, and for the forms by the square foot of the surface of concrete in contact with the forms. It is not apparent why this same method should be employed for columns, cornice, moldings, cast trim, and similar work.

Would not it be better to have the unit of measurement for work of this kind by the piece or the linear foot for the finished product? This, of course, is with the understanding that the unit price is to be determined from drawings that have been prepared which definitely fix the design and dimensions. Where contracts are made for work before the drawings are fully complete, units of measurements should be such as would permit the determination of the true value of each part of the work; but, if the contract is to be based upon competitive bids, some embarrassment may be experienced in determining the low bidder, if separate prices are submitted for concrete, reinforcement, and forms. For example: Based upon one set of unit prices, bidder A might be low, if some of the walls were made 15 in. thick, but if it were eventually decided, after starting the work, to make the walls 20 inches thick, bidder B might be the low bidder.

To consider the rules of measurement from the point of a unit price contract, if the unit prices for such items as columns, etc., were on a basis of linear feet, Rules 19, 20, 21, 22, and possibly 23, could be omitted. It is believed also that Rule 24 could well be omitted.

In connection with moldings, there should be a separate price for each different molding, or cornice. In this case, there would also appear to be no necessity for the measurement of forms, therefore Rule 27 might be omitted, and the same comment in connection with Rule 27, would apply to Rules 31 and 32.

It is considered also that the measurement of stairs should either be by lineal foot or tread or by the tread. In which case there would be no necessity for the separate measurement of the concrete reinforcement, nor for Rules 34 (a) and (b).

In connection with Rule 47, inasmuch as the unit price of this work in place would be based on the amount of material it would be necessary to purchase, and the amount of waste would vary with the position in which the material was placed, it is believed that there should be a modification.

Rule 52 states no allowance should be made for the protection of finish with sawdust, sand, etc. Inasmuch as this might affect the cost of the finished work, and that in some instances it might be required while in others not, should there not be a unit price for such protection?

Would it not be more convenient to make the unit of measurement for structural concrete other than the cubic foot, as referred to in Rule 62, it being understood that the unit price is to be based upon a piece of concrete of definite dimensions? And in this case, why should there be any unit price for the reinforcement as referred to in Rule 65?

Rule 66. The comment previously made relative to this rule would apply in connection with a unit price as a basis of contract.

Rules 69-75. For the purpose of a unit basis contract, it is believed that most or all of the rules for cast concrete trim and ornamental work might be changed, and a rule to the effect, that cost concrete trim and ornamental work, be either by the linear foot of the different kinds and sizes of the contract, and by the piece in special work.

Thoughts on Concrete Houses.

By J. C. Pearson.*

In preparing this paper I have not attempted to cover the general subject of concrete houses, even very briefly, but have confined myself to certain aspects or principles on which one might proceed if he were interested in building himself a good substantial home. I have also treated the subject largely from the structural point of view, wishing to emphasize the thought that the question of appearance and finish should be more completely separated from the structural problem than it usually is. Some of the finest concrete houses that I have seen show little or no evidence that the structural parts are of concrete, but this is largely a matter of personal taste. While I have included a few remarks on interior and exterior finish, I have had the structure itself uppermost in mind.

The relation of the concrete house to the housing problem, the advantages and disadvantages of the concrete house, and general problems in construction, are discussed at some length, the latter perhaps rather more in detail than would interest one who is not somewhat familiar with building construction. The "thoughts" apply particularly to those problems in concrete house construction which are not yet completely and satisfactorily solved.

In order that my treatment of the subject may not be too long, I have confined my remarks to the monolithic and the small unit types of houses, which have been most widely used in the small building operations. What is said does not necessarily apply to the large precast unit house nor to the reinforced-concrete frame house, although much of the discussion applies equally well to all types.

The Housing Problem and the Concrete House.

The housing problem which became so serious during the war is still with us, although it now presents a somewhat different aspect. From the point of view of the average person interested in building a home, the problem is whether one should invest $10,000 in a house that would have cost about $5,000 before the war, and whether one's need is great enough to warrant his facing the depreciation in values which will come when the index figure for dwelling houses drops from its present high level. The direct result of the existing high prices is that many who would prefer to own their own homes are trying to rent, and outside of apartments, desirable rents are scarce. If the frequently quoted figures of the U. S. Housing Corporation are correct, desirable rents in detached houses will be scarcer still in the future, or else people will have to accustom themselves to paying rentals which amount to 15 or even 20 percent per annum of the value of the property. The effect of these higher rentals,

*U. S. Bureau of Standards, Washington, D. C.

which will not return excessive profits to the owners, will undoubtedly be to encourage home ownership. Because of the greater investment required in building a home under present conditions, it is necessary to build more permanently in order to safeguard that investment. The prevailing opinion seems to be that the housing shortage will continue for some years at least, and the remedy for this condition is that people should go ahead and build, but be careful to build *well*, so that their investments will be secure, even if building costs are reduced later.

In numerous papers which have been presented before the Institute in the last few years we have been told that concrete houses are efficient houses, an opinion which is held by the very great majority of those who have had experience with them. It is important, therefore, that we should consider the concrete house in its relation to the better house program and broadcast the facts regarding its advantages, its practicability, and its further development. Any contribution on this subject should be welcome, especially if it outlines the construction problems and indicates how these are being solved by architects and builders.

CHIEF ARGUMENTS FOR THE CONCRETE HOUSE.

For convenience I shall refer frequently to the all-concrete house, meaning by this a house which has its structural walls, floors, and main bearing partitions of concrete, regardless of other materials which may be used in the exterior or interior finish. The outstanding advantages of such a house are four:

1. It is more sanitary than any other type, affording less opportunity for vermin to find thoroughfare or breeding and hiding places.
2. It is a very fire-resistive type of construction.
3. Its maintenance and depreciation are low.
4. It is of maximum stability and rigidity.

These advantages are fairly self-evident and I have no comment to make on the first, nor on the second, other than to mention the regrettable fact that our people are so indifferent to fire risk. Fire-resistive construction in dwelling houses is inseparably a part of the new order of building; in the all-concrete house we can have the highest degree of fire resistance.

The average person may, however, be less impressed by the usual arguments for fire-resistive construction than by a few simple figures which illustrate the meaning of reduced maintenance and depreciation charges. It is fairly well established that a proper maintenance and depreciation allowance for frame houses is about 5 percent per annum of the total cost. An all-concrete house, we are led to believe, can be built at a cost not greater than 15 or 20 percent above that of a frame house on substantially the same plans, and the maintenance and depreciation allowance on this type is estimated at about 2.5 percent. Neglecting taxes and insurance, which about offset each other in these two types, the annual carrying charges for the frame house are interest, say at 6 percent, and maintenance and depreciation, 5 percent, total 11 percent. For the con-

crete house the charges are 6 percent and 2.5 percent, or 8.5 percent. Assuming the cost of the frame house at $5,000 and the concrete house at $6,000, the annual carrying charges, exclusive of taxes and insurance, are $550 and $510, respectively. Thus the more expensive house proves to be the better investment, for the annual savings, although small, are sufficient to off-set the increased first cost in about 16 years, or slightly less than the period set by many building and loan associations for repayment of building loans. If the difference in the first cost had been 15 percent in the example given, the period necessary to off-set this amount by the annual savings in carrying charges would be less than 10 years. The thought I wish to emphasize here is that the first cost should not be the determining factor in the purchase or building of a home, and that if one were required to pay even 25 percent more for an all-concrete house he would find it a better investment in the safety, comfort, and satisfaction of living in a home that was practically safe from fire, and free from many of the faults that develop in the ordinary house.

The fourth argument for the concrete house, maximum rigidity and stability, is a most important one, for these are the qualities upon which low maintenance and depreciation depend. Rigidity and stability of the frame do more than this, however, for they not only tend to preserve the house in its original condition, but they save the house owner and housekeeper from continual worry about the unsightly appearance of cracks in the plastering, the separation of baseboards from floors, the annoyance of sticking and non-latching doors, sags and humps in floors, and other ills of like nature.

CHIEF ARGUMENTS AGAINST THE CONCRETE HOUSE.

There are certain disadvantages of the concrete house which we must recognize at the present time, even though they are not all to be regarded as such in the future. Bearing in mind that we are discussing the subject from the point of view of the prospective home-owner, we may list the following objections in the order of increasing importance:

1. Prevalence of opinion that the concrete house is likely to be cold, damp or unattractive in appearance.
2. Higher first cost.
3. Building code restrictions.
4. Lack of builders who are interested or experienced in this type of construction.

The first of these objections is valid only to the extent that one may be unfavorably impressed by certain existing examples of concrete housing which, in the endeavor to find a place in a cheap competitive market, have suffered from the omission of essentials, not only in finish, but also in proper wall insulation. The problem of insulation is not different from that of any masonry house, and in fact there are several systems of concrete house construction which provide the necessary insulation within the wall, a provision which is not as successfully and easily accomplished

in any other type of rigid construction. It is true that there are many ugly examples of concrete houses, but the most of these are to be found in commercial and industrial housing projects, where pleasing finishes are deliberately sacrificed to cheapness and utility. This first objection is, therefore, not founded upon fact, and does not need to be seriously considered. Observation indicates very clearly that a concrete house may be made as attractive as any other, and in fact has possibilities of its own for distinctive treatment.

The second of these objection, higher first cost, is unfortunately too often the deciding factor in the building or purchase of a home. It has been shown, however, that the additional expense entailed in building with concrete is a wise investment, as it means a saving in the end and carries always certain advantages in the nature of a direct return. The higher first cost is not, therefore, a valid argument against the concrete house, for it is the justifiable higher price of a better product. But there is a real objection to higher first cost when this includes a premium upon the ignorance or inexperience of the builder. This is a condition which has to be faced during the introduction of new methods and processes in building, and we must recognize that *too high* first cost is a real obstacle to building these better concrete houses.

Present building code restrictions are in many cases a very serious handicap upon concrete houses, especially those of the monolithic type. At the present time the Federal Department of Commerce is striving to eliminate waste in industry and building construction, and it is gratifying to note the progress which is being made in cutting out unnecessary restrictions governing the thickness of masonry walls in houses. It is particularly gratifying to note the recognition of various types of concrete house construction in the recommendations of the Department's Building Code Committee (Recommended Minimum Requirements for Small House Construction), which also embodies suggestions substantially in agreement with the recommendations of your Committee S-5, on Reinforced-Concrete Houses. If the general provisions of this departmental report are made the basis for small house requirements in city building codes throughout the country, one of the great obstacles to efficient concreate house construction will be removed. I wish to emphasize the thought however, that until these changes are generally introduced, the concrete house will be handicapped by traditional requirements which have been imposed upon older and inferior types of construction.

The greatest disadvantage of the concrete house at the present time is that comparatively few builders have had any experience in building houses of concrete. The majority of small builders will not take the initiative in this matter, and will wait for a general demand to be created before they become sufficiently interested to inform themselves regarding efficient methods, but I believe it is ultimately through the efforts of progressive builders, and not through promoters, that the concrete house will come into general use. The architect will also contribute his share

in this development, but it is the associated architect and builder who will eventually solve the individual concrete house problem. We have the basis for a great many possible solutions of this problem in the multiplicity of "systems" of concrete house construction, but none of these can be accepted as a real solution until it has been thoroughly tried out and kept going with increasing momentum for a period of years.

CONSTRUCTION METHODS AND PROBLEMS IN BUILDING THE CONCRETE HOUSE.

To get the full benefit of concrete in house construction it is desirable that walls, floors, and at least the main bearing partitions be built or framed in concrete. At first this sounds somewhat radical, but we are well aware that larger structures such as hotels, apartments, and public buildings are economically built of reinforced-concrete, and there is no reason, a priori, why this same sort of construction cannot be extended to small structures, such as dwelling houses. This has been done successfully in large operations, but in very few cases extended to individual homes. One of the chief reasons for this state of affairs is that special equipment and knowledge are required by the builder, if good concrete houses are to be built at a sufficiently low price to create a general demand. At the present time there seems to be more equipment available than knowledge, but neither equipment nor methods have been worked out on sufficiently broad lines to indicate clearly how the individual concrete house will eventually be built. The intrinsic merit and superiority of the all-concrete house warrant, it seems to me, encouragement of effort not only on the further development and standardization of this type of construction, but on a broad program of research and education, in order that the product may become more generally available at a cost which will be attractive to people in moderate circumstances.

In the face of many difficulties in selling the all-concrete house, we see many promoters of concrete construction making more or less headway with houses constructed partially of concrete, in which the particularly expensive item of structural concrete floors is omitted and the concrete in most cases confined to the exterior walls. While the concrete-walled house lacks much of the intrinsic value of the all-concrete house, the gradual introduction of the latter may perhaps best be brought about by getting the public accustomed to the idea of the cheaper concrete houses and eventually to the general acceptance of full fledged concrete houses in this manner. Thus we may congratulate the Portland Cement Association in recently establishing a Concrete House Service Bureau, even though the recommended concrete block or tile wall construction is only the first step toward the really superior all-concrete structure.

With particular reference to the concrete-walled house, whether it be of the small unit or monolithic type, a warning should be sounded against over-rating either the fire-resistive quality, or the expectation of low maintenance and depreciation, if the interior framing is of wood.

A very large proportion of all fires originate on the premises where they occur, about 95 percent of the entire number, I believe, or about 83 percent on the basis of total fire losses. The mere fact of an exterior wall of concrete or masonry does not, therefore, have much effect on the fire hazard in a dwelling house, although liability of total loss may be lessened thereby. Insofar as maintenance is concerned exterior walls of concrete reduce the cost of exterior painting considerably, but if the interior framing, particularly of the main bearing partitions contains any appreciable amount of horizontal wood, the plastering and the general interior condition are likely to be in worse shape after a round of seasons, and at all times subsequently, than in a well-built frame house. It is most important, therefore, in building the concrete walled house, to take all the precautions for fire protection of the interior that are recommended for wood-frame houses, and to make special effort to eliminate horizontal wooden supports in the bearing partitions. If specifications for concrete-walled houses include the additional requirement that main bearing partitions shall be similar to the exterior walls, or of equally rigid construction, the interior of such houses will be maintained in better condition than will be possible if the interior framing is entirely of wood.

WALLS.

The ordinary concrete wall, whether monolithic or of the small unit type, needs insulation of some sort, even in moderately severe climates. The most common practice is to fur with wooden strips and lath and plaster the interior. Certain types of concrete blocks are designed to give a continuous air space and this avoids the necessity for furring and lathing. The same result is accomplished by the monolithic double wall, and so far as our present information goes, any type of wall that presents two air tight layers of solid material separated by an air space offers a sufficient barrier to the passage of heat to make an acceptable dwelling house wall. If these layers are connected by webs or cross ties of metal, concrete or masonry units, which form any considerable percentage of the wall area, the insulating value of the remaining air space is largely ineffective, hence the necessity for furring and lathing walls of concrete block and tile. In the case of the cinder block or the monolithic cinder concrete wall, a dry pressed or dry tamped mix may be a sufficiently poor conductor of heat to warrant omission of furring and lathing and if at the same time the necessary strength is obtained, this type of construction may afford a double measure of economy. At least one other type of wall is worthy of mention, and that is the thin solid slab lined with a good insulator, such as cork board or fiber board. This method of insulation promises to be economical and effective and if it permits of satisfactory interior finish, which is independent of wall plaster, it will be a strong point in favor of the small monolithic house.

There is little exact knowledge, however, concerning either the absolute or relative heat transmission of different types of walls; the problem

of determining this property is much more complex than it appears to the layman. It is hoped that the Bureau of Standards will, within the next two or three years, be able to carry out a comprehensive investigation of this problem, and it is gratifying to be able to report that preliminary tests on a limited number of typical wall sections have already been undertaken, mainly to establish the methods which should be used in carrying out such a series of tests.

FLOORS.

The problem of floors in the concrete house, or in any type of brick or masonry house that is so built as to qualify in the vermin-proof, fire-resistive, low-upkeep class, is the most important and the most serious of any that we have to solve at the present time. Moreover, it is an economic problem entirely, and consequently of greatest importance in its relation to the moderate priced home.

In suggesting the propriety, and from an advanced point of view, the necessity, of putting concrete structural floors into the concrete house, we must recognize the fact that people are accustomed to wooden floors, and until they are educated to a different point of view, will generally demand them. But a concrete slab of standard design, with wooden top floor and a space underneath for pipes and conduits, is a very expensive type of floor, too expensive in fact to go into any but high-priced houses. It is found, however, that the elimination of the wooden top floor and the exposure of a few pipes, which should not be laid in the structural slab, reduce this cost very considerably. Many people have tried the plain concrete floors and find that there is much less objection to them than most people imagine. Rugs and other coverings may be used on the concrete floor with just as much satisfaction as on the wooden floor. But even so the standard flat slab floor is too expensive, and if built according to recommended practice it affords an absurdly large margin of safety. The reason for this seems to be that present standard design does not apply satisfactorily, that is, economically, to the low-load, short-span conditions prevailing in most dwelling houses. There seems to be something fundamentally wrong with a floor design which involves a dead weight from two to four times as great as the maximum live load the floor will ever be called upon to carry.

There are two possible solutions for the concrete floor problem. One is that by some ingenious scheme an acceptable design can be found where the forms or the reinforcement, or both, may be made to serve a double purpose. A scheme of this sort was described in the paper by H. Whittemore Brown before this Institute a year ago, but the method used by Mr. Brown would probably not be generally applicable. The other solution is to thoroughly test out some new designs that promise to meet these special small house requirements. Certainly there are not lacking a multitude of suggestions for such designs. I believe there are a number of ways in which this problem of concrete floors for small houses can be

worked out satisfactorily; but, after all, what we need is facts, not beliefs, and the sooner these facts are established, the sooner can the small concrete house be built at a cost comparing favorably with that of the frame house. There is nothing more essential than such a series of tests to the building of better houses at lower costs.

The Bureau of Standards would like to undertake this investigation. It has the necessary facilities and part of the technical staff. Unfortunately the funds appropriated by Congress are not sufficient to enable it to employ the remainder of the staff and the skilled mechanics needed. However, it can accept the co-operation and assistance of interested organizations and would welcome such co-operation at this time to enable it to work on this problem. It may be stated that other interests, among them the Brick, Hollow Clay Tile, Architectural Terra Cotta, Limestone, Lime, and Gypsum Associations have taken advantage of these conditions, and have placed men at the bureau to assist in working out certain problems.

The cost of the proposed series of tests would not be at all prohibitive. There are so many large groups vitally interested in the results of such an investigation, that a small fund appropriated by each for a co-operative research would permit the carrying out of a well rounded and conclusive investigation.

In the meantime there is a possible compromise between the concrete floor and the wood joist floor in the use of light weight pressed steel beams. Somewhat more than a year ago I had an opportunity to inspect the steel lumber and stucco house in Canton, Ohio, built by the Berger Mfg. Co. of that city. I was particularly interested in the floor construction, which seems well adapted to any type of concrete house because either wood or concrete top floors can be economically used. The construction which appealed to me as meeting most of the requirements was steel joists of suitable dimensions overlaid with two inches of concrete and protected underneath with metal lath and plaster. If the wood top floor were desired, nailing strips would be fastened to the beams before placing the cinder fill, and the wooden floor nailed in the usual manner. I am indebted to the Berger Mfg. Co. for an estimated cost per square foot of this latter type in place and ready for the wood floor, at 36c. per sq. ft. This is for a floor of 14 ft. span, carrying a live load of 30 lb. per sq. ft., the weight per square foot of finished floor being given as approximately 35 lb. I do not know how extensive the data is on which the performance of these floors is based, but the type should certainly be included in any comparative series of tests, such as the Bureau of Standards will undertake if those interested will co-operate to the extent of providing part of the funds required.

PARTITIONS.

The main bearing partitions of the concrete-walled house should be of rigid construction. The choice would naturally be concrete building units when these are used for exterior walls, but steel or reinforced-con-

crete beams, monolithic concrete or any suitable type of masonry may be selected that will prove most economical for the plans. In the all-concrete house or in the concrete-walled house with rigid main bearing partitions and protected steel lumber floors, minor partitions can economically be framed in wood. Not more than 4 in. of horizontal wood is required for the two nailing plates, and the shrinkage or distortion would probably not be great enough to result in appreciable deterioration. Metal lath is preferable for such partitions, and wood-top floors, if used, should be laid after the partitions are framed in place.

Roofs and Porches.

It seems to me that the roof and porches of an all-concrete house, in the sense that I am using the term, need not be constructed of concrete, although concrete can often be used to advantage in both. The point of view is that the chief structural parts of a house cannot be built of better material than concrete, and if the rough structural shell has been properly designed and constructed, the chief advantages that concrete has to offer have been assured. The main purpose of the roof is to protect the dwelling and its occupants from rain, snow, heat, and cold, and also to afford an acceptable architectural treatment. Whether the space between the roof and the living quarters is simply an air space or utilized for storage purposes, its construction in wood frame would be entirely consistent, provided it were covered with incombustible roof covering and fire stopped at the eave. An added safeguard would be provided by covering the rafters with metal lath and plaster, and this would be desirable in any case for insulation purposes, making the house warmer in winter and cooler in summer. With these precautions the roof framed in wood or metal lumber should be entirely acceptable, and for a number of reasons should be preferred to a concrete roof.

If the occupied rooms are partially enclosed within the roof space and are not entirely separated by fire resistive construction from the spaces enclosed by the roof, all the precautions mentioned in the preceding paragraph are desirable and necessary, if the dwelling is to be consistently fire resistive throughout.

In porch construction concrete is to be preferred for the floor, but personal taste and architectural preferences may dictate the use of other materials, especially for the super structure. There is no objection to such construction if on account of expense or for other reasons the all-concrete porch is not desired.

Interior Finish.

The time is coming when we shall see radical changes made in the methods of finishing the interior walls and partitions of dwelling houses. Many hold the opinion that the practice of applying wall plaster by hand is gradually to be superseded by better and more satisfactory methods.

We are led to believe that plain white walls and ceilings will give way to fabricated coverings of various sorts which can be arranged in attractive panel effects avoiding the mess which the plasterer leaves behind him and the delay occasioned by waiting for the interior to dry out properly before applying the trim and decorative treatment. The concrete house may help to solve some of these difficulties in the opportunity it offers for skillful manipulation of the concrete itself, but in any event it is well adapted to receive any sort of interior finish, and to preserve that finish from deterioration through the stability of its structure.

EXTERIOR FINISH.

The exterior treatment of the concrete house offers many possibilities, depending upon the "system" or type of wall construction. One's first thought is naturally of stucco, and this treatment will undoubtedly be prescribed for the very great majority of monolithic and block houses. Fortunately concrete is, so far as we know, the most suitable base on which to apply portland cement stucco, and the most satisfactory results are to be expected thereon, whether the stucco be of the spatter dash variety applied with a paddle, or whether it be of the exposed aggregate type requiring the greatest skill in application. I might say a great deal on this subject, but I should like to call attention to the fact that certain systems of wall construction which give a flat uniform exterior surface can be very economically and very attractively finished by a single wet dash without the use of the trowel. The cost of such a finish is only a fraction of that of the usual two coat or three coat work, and this fact ought to be some inducement toward producing more accurate surfaces in the structural wall. If the wall to which such a dash is applied is not too dense and the proper condition of suction is assured by an intelligent workman, this finish is likely to be as free from imperfection and as permanent as the most expensive stucco finish.

I am not at all sure that such a finish could not be successfully applied to a block or tile wall that was laid in a mortar of about the same degree of absorption as the unit. I believe this would be well worth trying on a small scale, and I hope that some of the block and tile manufacturers will be sufficiently interested to carry out some experiments along these lines.

It has been well established by numerous examples of group housing that houses of similar plans and similar structural design can be finished in such way as to give the appearance of being quite different houses. This is accomplished by the use of different types of roofs and porches, and by variations in the architectural and decorative treatment, for example in orientation, in finishes of brick veneer and different colored stuccos, in details of entrances, etc. This flexibility is of considerable importance in its bearing upon the individual house problem, permitting the desirable individuality of appearance in many houses from a limited number of good standardized designs.

SUMMARY AND CONCLUSIONS.

In review, let us hold to a clear prospective of the concrete house in its relation to the better house program of the future. Granted that we need better houses, that is, houses more nearly vermin and fireproof, costing less for maintenance and depreciating more slowly, we find that the concrete structure approaches closely to the ideal. Let us emphasize the *structure,* for herein lies the greatest value of the concrete. At the same time let us remember that the concrete house is as susceptible to architectural treatment and as capable of being made into a beautiful home as any other.

There are some obstacles to the rapid introduction of the concrete house, chief among which is the lack of experienced builders. This not only retards development, but tends to make the present cost excessive and the cost is also higher than it will be eventually when economical design has been worked out and established by investigations and tests. Some of the more important problems have been outlined, none of them more pressing than the development of a satisfactory light weight concrete floor. In the meantime the nearest approach to the all-concrete structure seems to be the concrete-walled house with rigid main bearing partitions and steel lumber floors.

What seems to me to insure the place of the concrete house in the building program of the future is the intrinsic soundness of an investment in this type of house, even in the face of somewhat higher first cost. This, plus the knowledge that the concrete house is highly fire resistive and free from continually developing defects, should make certain its ultimate success.

I hope that the members of this Institute, from their intimate knowledge of concrete, will take an active interest in the further development of the concrete house. The business of building houses may not attract the great majority of us, but the great majority of us have to live in houses of some sort, few of which are entirely satisfactory as to fire risk, or entirely free from the structural and other defects which I have mentioned. It develops one's powers of observation and deduction to analyze some of these defects, trace out their causes and determine how they could be avoided. In my opinion the best ultimate solution is that reinforced-concrete shall be built according to standardized plans, by methods which will be tried and improved through experience. But there are other types of concrete houses which may be equally satisfactory. It is a great economic problem, and *any* solution which leads to the construction of better dwelling houses at reduced costs will benefit all mankind.

A New Art of Concrete; An Address.

By Lorado Taft.*

If I were to attempt to register tonight the enthusiasm which I feel for concrete, you would think me something like an ardent old lady writing a testimonial for Peruna: "Having drunk a thousand bottles of it, I feel that it saved my life." This material has saved my life on two occasions; it is no wonder then that I like to talk about it. The first experience may not interest you particularly but I must tell it.

Some twelve or fifteen years ago—the years are counting up so fast now that I cannot keep track of them—but some time ago we were standing one evening on the bluff of Rock River, a group of us, looking at the sunset. We are a little family of artists who have camped there now for twenty-five years. We are almost fire worshippers—sun worshippers—and every evening we gather and look at the sunset. It came over me on that particular occasion that this would doubtless be done for generations to come, and then I harked back in long retrospect and thought of the generations who had preceded us and gathered there also and looked on the setting sun across the river. Out of that thought grew an immense figure, one of those absurd undertakings of a man who has no money, a figure they call "Black Hawk," an Indian wrapped in his blanket, very simple and massive and craglike.

In its simplicity it reminds me of Oliver Herford's delight in drawing Napoleon; he said that as a boy he always liked to draw his picture because he had one hand in his coat and the other behind his back, and there was no trouble about drawing the hands. So I wrapped up my figure; it had no details at all but an Indian head emerging from the crag and looking sadly over the scene. I sketched the image and it grew larger and larger—still I was uncertain of my material. I did not know what I was going to do about it, but in the meantime, without regard to cost or intention, the figure continued to grow.

I remember that we hit on rather an ingenious method, as it proved, of locating the statue. I got a hayrack and some scantlings and stood them upon it, an effect something like an Indian wigwam especially after I had wrapped them in old tent-flys. This was supposed to suggest the figure. We pulled the hayrack round in different places on the bluff to see where it would fit into the landscape best and went downtown to look at it. It was all right, only one couldn't see it. It was too small. That taught me that we must make it twice as big, and I began again with scantlings 20 ft. long and lengthened them out to 24, and so we doubled it and made a figure 48 ft. high, on a base some 6 ft. above the earth. This was satisfactory from a distance; we could see it from downtown.

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*Chicago, Ill.

About that time I saw men making a reinforced-concrete chimney in Chicago and I felt convinced that if they could make reinforced-concrete chimneys, we could make reinforced-concrete Indians; and so, just muddling along, groping our way, this thing developed. About the time I was completely stuck, without means, I heard from some unknown friends of the Universal Cement Company who offered to contribute the cement. I don't know what for—never did know—but it came, car-loads of it, and I am sure it helped out very much; my family and starving children appreciated it greatly. And so finally the figure was erected and completed; we had worked a couple of years on it. It was quite a sight to the neighbors and people wondered what I was doing it for and sometimes asked me so pointedly that I wondered myself. But it was simply a matter of filling in the landscape; it needed that figure, I felt perfectly sure of that.

I remember we got our mold completed about Christmas. I have forgotten what year it was, but I know that just as we were ready to pour the cement, the thermometer went down to zero and it was a fairly trying occasion. Perhaps I should explain that our mold had been built around a construction of scantlings covered with chicken-netting. This was covered in turn with burlap which was merely painted over with plaster water giving us our body. All had been done by carefully measuring in from a 6 ft. model and multiplying seven times. The head we had modelled in clay on the ground. It was about 6 ft. high, including the neck, and made quite a heroic looking, sphynx-like creature on the earth. On that we made a piece-mold; the head was hoisted into place and tried on, and then we took it away and put the piece-mold up in place of it, on top, and we were ready for the casting, but, as I said, the temperature was unfavorable. Here was our immense plaster mold. We felt perfectly sure that in spite of its scaffolding and guys the first storm would grind the whole thing to pieces. My money was gone and I never would be able to undertake it again; it was now or never. We borrowed three little boilers, made steam, warmed the cement, the sand, the aggregate—we used screenings of red granite from Wisconsin—and the thing was poured. It was a tragic or at least a dramatic time, and all the circumstances added much to the suspense.

You can imagine then the anxiety with which I went out there the first mild day in March and climbed that scaffolding to see how it had stood the weather. I broke off a piece of the mold from one eye, and "Black Hawk" looked out sadly but confidently over the Rock River Valley. His eyelids had not been frozen off! We had dried him a little before we went away and he had stood it all right. This was experience No. 1. It just shows how one gropes his way along toward something uncertain but which may develop into an object of value. I may add this, that of all the efforts I have made in the past, that simple, massive, crag-like figure has counted more for my reputation than all the rest put together; not because it is very good but because it is in the right place

and has a certain amount of sentiment in it. At many hours of the day it is just a pile of concrete, but at other hours, especially in the evening, it may be very impressive. One evening we had Percy Mackey, the poet, out there and brought his canoe around the bluff—why, we didn't know but that he was going to expire, he had so much emotion.

Then came this other experience. I had gotten myself in another very serious predicament. That "Fountain of Time" is—or was—a part of a comprehensive scheme for the decoration of the "Midway." I do not see anyone here old enough to remember the World's Fair in Chicago, but will explain that the "Midway" was the sideshow of the Columbian Exhibition. It was long since fumigated and reconsecrated, and is now a very beautiful and broad avenue which is virtually the campus of the University of Chicago, the University having bought the property on both sides of it. So, in a way, it is consecrated ground, a very sacred place, although largely occupied by frivolous automobile joyriders. Long ago I settled in that neighborhood, on University property, and looking out of my window daily, began to embroider the "Midway" with imagined sculpture. I wondered what they would do with it in Europe—how it might be embellished—just as a decorator would look at a wall and wonder what he would do to it. Naturally I thought of a fountain at either end, a monumental fountain to make a vista. We Americans seem to think a vista is a hole to look through. In Europe it is something to look at. It was not so easy to think up a subject for a monumental fountain, but one was given to me for the east end, against the Illinois Central track. Almost every one in Chicago has something against the Illinois Central, you know; why shouldn't I?

A lady said to me once "I wonder that you modern sculptors have never used the theme of Ducalion and Pyrrhae, and went on to explain that Ducalion was the hero of the Greek legend of the flood. I recalled the story that I had read and forgotten of this Greek Noah and his wife and their adventure. They came down from Mount Parnassus, according to the story, very sad and lonesome, having only themselves for company, and inquired of an oracle what was to be done to replenish the earth—some short method—and the answer came back "Cover your heads and throw the bones of your mother over your shoulders." In some way they interpreted this to mean Mother Earth and that her bones were the stones, and Ducalion threw stones and they became men, and his wife threw stones and they became women. I do not vouch for the story; it is as the papers say, "important if true"; but I saw its possibilities. It is one of the most sculptural themes imaginable. I can see those rocks taking form and coming to life. I was afraid for years that Rodin would get hold of it because it is just the sort of thing he knew how to do; but he is safe now. I have desired, beyond anything I can think of—except saving the old Art Museum in Jackson Park—to make that fountain. Nobody wants it but myself, but I want it "the worst way." In addition I wanted to make some bridges; a Bridge of the Sciences; Bridge of the Arts and

a Bridge of Religions, crossing the possible canal planned to go through the center of the Midway. Finally I designed this fountain which you have seen on the screen called the Fountain of Time.

It was derived from two little couplets written by Austin Dobson—all I ever read of Austin Dobson. Fortunately, I did not read a whole book for these two lines kept me busy some seven years. "Time goes you say; Ah no, Time stays, we go." I tried to think how that could be expressed in sculptural terms. Time, like a crag, something like my "Black Hawk"; and humanity, I could see, as a series of waves betokening the ephemeral. I think it was Huxley who used to say "the individual drop rises and falls; the wave sweeps on." I remember I first designed it with Time in the center of a circle, like a ringmaster, and these waves going round and round him; but I thought the public would soon get on to the fact that they were just chasing themselves, and it seemed better to draw them out into a procession. I made my little models, and then, to my great surprise and almost consternation, the thing found favor in the eyes of people in authority and they gave me the order to go ahead with it. This is very embarrassing to an artist who is accustomed to dreaming only. They asked me what it would cost. I estimated that it would cost me about ten thousand dollars a year for five years. That was just a guess. It cost it all right, for it took me six years or more to make the model; but it kept my little brood of young sculptors busy and a pleasant time was had by all. Then you know what happened; the World War came.

I do not want to hurt my friends of the Georgia Marble, but I learned after a while that in one of our cemeteries marble was no longer considered, that marble was not standing the strain of our climate, so I regretfully gave up the marble, especially when I found that my friends the carvers in New York, the Piccirillis, the most experienced and best equipped for such work, said they could not give me an estimate on it. That was two or three years ago when nobody cared to work. I don't know what they lived on, but they would not give me an estimate. I trust that this was not in any way on account of my unreliability. Meantime the procession had gotten to be 120 ft. long; there were ninety-nine figures and then a baby—we hadn't expected the baby—that made it an even hundred. And there we were! Really it was embarrassing for one who had invested so much who had put it out there as a kind of trust fund. I had been using $50,000, and now the plaster was waiting.

I could not bear to think of putting that thing in bronze. I like bronze for certain purposes, but I had conceived of this as something white and foamy, like the waves, and to put it in bronze seemed to me very incongruous. They talked of Bedford stone; I have great respect for that material but it did not appeal to me in this case and there remained the great problem of getting it carved. I would much rather have seen it in white granite. Surely I needed help and counsel. Then one pleasant gentleman named Mr. Gilkie told me of a very considerate gentleman named Mr. Lord and Mr. Lord sent me to a gentleman of the

Bureau of Standards who, they said, could tell me all that was known about concrete, and Mr. Pearson wrote a kind letter recommending me to Mr. Earley, and it was one of the happiest days of my life when I met Mr. Earley.

To be sure it proved rather hard to interest him; he was pleasant and courteous, but he has his dreams, too, and has been working on his material like another Della Robia, trying to find something that would be serviceable, artistic and appropriate for the various uses of architecture. He has found it. I am confident that he and some of you experts are on the verge of one of the greatest steps in American architecture and American art in general. Mr. Earley finally became interested in the fountain; you have seen some of it here and will see the rest of it when you come to Chicago. The men began making the mold about a year ago, in zero weather, in Chicago. They were under a shed. Sometimes they did not notice that the shed was there. It was a trying time, but we made up for it during the summer. The good work went on; they spent six months making that mold. You can imagine my emotion when they began to fit those things together and to pour it; they did it so differently from the way I should have done it. They had so many considerations that never would have occurred to me, steel construction inside and things like that, but I just accepted them without question, and when we got the result it combined two great qualities.

Most people when one speaks of concrete, think of pavements and the color of a sidewalk, but here is something new which combines two very advantageous qualities in sculpture. We used to spend weeks in the Beaux-Arts days in Paris, after shaping a figure and modeling the flow of its surface, in going over it and putting little dabs of clay on it, you know, to get a littls sparkle into it, a little vivacity—well, you don't have to do that any more. Just make it of this aggregate of pebbles and wash away the cement and you find your little dabs there; it has a wonderful effect. But more than that, as you have seen in those samples, is the combination of colors which gives you a "pointellist" painting. Mr. Earley took me into a vestibule in Washington—one of the most beautiful things I ever saw. You go up to it and feel of those moldings and they are hard and sharp—done with the firmest stroke, and yet from a distance they have almost the sparkle of a pen-and-ink drawing.

I am telling you things that you know better than I do but I wonder you don't go out and shout it from the housetops and get people interested. It is coming so slowly. One of our most intelligent art connoisseurs in Chicago said, "I don't know but what we will be driven to using cement blocks in the University buildings"; but when I think of the possibilities of monolithic work which he does not know anything about yet, I am astonished at the inertia of humanity. I have had two wonderful experiences in the last two days. One was in that church which Mr. Earley has recently completed in Washington, the interior all in color. I do not know what that Byzantine decoration would cost in mosaic, but I'll

guess this was not a tenth part of what the other method would cost. The mosaic maker will pick up his little stones with a forceps, perhaps, and lay them in. Mr. Earley apparently does it with a pepper box, but the result is beautiful. Yes, the results are perfectly marvelous in their vibrancy and harmony. I experienced some more thrills when I went down and saw another of Mr. Earley's jobs at Nashville. Possibly the exaltation came in part from the fact that my little girl was acting down there and doing very well. I vibrated between the "Cat and the Canary" and their agonies, and the Parthenon. The Parthenon I visited four times while I was there.

Perhaps you are not informed in regard to this building, but at the time of their state centenary they constructed an art palace in the form of the Parthenon. It was built with a great deal of precision and was very effective, but after all it was only of staff with a "cella" of brick. Now Mr. Earley is making it over in the same material which we used on the Fountain. Well, you know, the beauty of it gave me something of the feeling I had on mounting the Acropolis in Athens. I have been there twice and I hope to go again this coming summer if there is anything left of it in the general eruption, but I had something of the same emotion as I looked on the solidity and charm of line and the classic impressiveness of the great structure in Nashville. I was telling Mr. Earley today that that place is going to be a school of art and have a wonderful effect on the citizens of Nashville. They have arranged lights behind the columns, and I thought of the Greek plays and pageants that could be enacted there.

If I seem unduly enthusiastic about all this it is because I have had the opportunity of doing some large things in sculpture and know the difficulties of the work. If you knew how disappointing every artist's work is to him; if you could compare the dream he had and the result you would know how humble we feel when we get through. And yet how it is needed! This great country of ours is full of monotony, of arid, inartistic spots. My rich state of Illinois has four hundred towns of over a thousand inhabitants. Not many of them have places that one would care to take a friend from abroad to see because of anything man has created there. They compare so badly in that respect with European villages with their wealth of historic associations, towns where everything is picturesque and wonderful and interesting. Here in America people grow up and grow tired of their home-town and try to get away from it. As one of our novelists has put it, "Every train that goes through a country village tells of a promised land somewhere else; it is a cloud of smoke by day and a pillar of fire by night, alluring and inviting." The youth of the country is led by this terrible drag, this tremendous gravitation toward the great city and you know what happens to them there.

I think it is an unwholesome condition. I think there is something more important than the veneer of civilization, there is something vastly important in making the home town lovable and lovely for those

who live there. Now by this new process it is possible that our home town shall have beautiful little fountains and monuments and decorations as exquisite in design as the world can produce and yet created at a comparatively small expense. That is why I am enthusiastic about this thing.

I do not know what our architects are thinking of in not attending these meetings. I supposed that half of you were architects, but I understand the architects do not come. I presume they leave it to the engineer partner to come, but it seems to me that we are, as I said, on the verge of one of the greatest developments in American art, and so I look forward eagerly to what will be reported a year from now and two years from now. Some of the buildings shown here tonight were very charming.

Let us enter into this discovery with a spirit not only of desire to make good returns, good profits in our work, but with the feeling that perhaps we are doing something very great and noble for America.

Building the "Fountain of Time."

By John J. Earley.*

Mr. Taft's generous acknowledgment of the work of my studio in preserving his "Fountain of Time" in concrete is a great encouragement to me and to the men associated with me and who have devoted their time and effort to the mastering of a difficult and complicated technique. I wish, therefore, for the members of my organization as well as for myself to gratefully acknowledge the tribute which Mr. Taft has paid to our work.

Mr. Taft was beset by the same trouble which has harassed sculptors for many years; namely, the cost of preserving his work in a permanent material, a difficulty which has always exercised a restraint on the practice of the art and at certain times has almost completely discouraged it. Mr. Taft's problem was particularly difficult because the Fountain of Time, which is probably the largest group of sculpture on a single base in the world and on which he had spent seven years of labor and $50,000, would necessarily be lost unless an additional $250,000 would be found available to pay the cost of translating his work into stone or metal or unless another material could be found which would be both economical and artistic. Mr. Taft's previous experience with the figure "Black Hawk" of which he has so delightfully told you, prompted him to believe that his Fountain of Time might be preserved in concrete if one could be found who understood the medium and who appreciated the artistic requirements of the subject. Whatever may be said of the Fountain of Time as an achievement in the surface treatment of concrete should never lessen the fame of Mr. Taft who is the foremost of his profession in expressing a faith in concrete as an artistic medium, and in giving to another's studio the opportunity to demonstrate the artistic fitness and the economy of concrete.

The economy and adaptability of concrete rests upon its plastic nature. It is well known that less force is required to work and to form a plastic than a solid mass and whether that force be considered as fuel or as labor less force certainly means less cost. Likewise when more perfect knowledge has permitted the development of a more perfect technique plastic masses will be more adaptable than solids, they will be under more perfect control and with better control will come better products and greater economy.

Only when we are able to do all the work that must be done to concrete while it is in a plastic state will we be able to appreciate the possibilities of this wonderful material. Concrete as an artistic medium becomes doubly interesting when we realize that in addition to its economy it possesses those properties which are the most desirable of both metal and stone. Metal is cast, it is an exact mechanical reproduction of the artist's work, as is concrete; but metal because of its color and the peculiar quality of its surface is hard to use, that is, it is hard, particularly

*Architectural Sculptor, Washington, D. C.

hard in large subjects, to fit into ordinary surroundings. On the other hand stone has a color and texture which is easier to adjust to general use and environment, than is concrete, which is largely stone, which partakes of the properties of stone and which when surface treated as was the Fountain of Time has a surface almost entirely of stone; but stone is an interpretation of an original work and is more often than not carried out by another than the original artist.

I frankly admit that the Fountain of Time presented the most difficult problem of its kind that has ever been brought to my studio. Unlike

FIG. 1.—STRUCTURAL BASE OF "FOUNTAIN OF TIME."

Upon this the contours have been erected, the forms of the roof slab and of buttresses which strengthened the outer walls of figures.

other sculptural groups which are usually composed of separate figures on a common base touching each other only at certain points this great group presented a wavelike mass from which projected and into which receded nearly one hundred colossal figures.

I will not present to you the usual processes of casting concrete in a plaster mold but will indicate where in the processes employed in casting the Fountain of Time differed from ordinary practice.

The features of the work which introduced unusual requirements were, first the shape of the group which was a continuous structure and not a series of assembled units; second, a complex fold which instead of being a receptacle into which the concrete could be poured was a dome

under which it must be placed and with which it must be maintained in contact while hardening; third, a core which would generally follow the configuration of the mold at a certain distance from it to regulate the thickness of the concrete and to support it in place, in contact with the mold while setting; and fourth a concrete which would fill perfectly all the re-entrant angles of a complicated mold, would not change volume and shrink away from the mold while setting, would attain an early strength to permit the removal of the mold and the exposure of the aggregate before final set, and which would when cleaned present a surface of predetermined color and texture.

We were considerably concerned about what to do with water which might collect in hollows among the figures. If we altered the shape of the mass sufficiently to eliminate the hollows we would naturally change the design of the group. But Mr. Taylor, my associate in the studio, solved the problem by resolving the entire structure into the elements of a house; a foundation, a first story, a second story, and a roof. The roof was built as high as possible but yet below a level at which the figures met in a continuous mass. It was pitched towards the center and drained by down spouts. The figures which formed the second story extended above the roof as an irregular parapet. They were arbitrarily divided into twenty-six sections of such size as estimated to contain the amount of concrete which could be placed in a normal day's work by the most efficient number of men. The joinings between sections were always vertical and located in recesses. The first story and the foundations presented no unusual features.

A cup may well represent a simple mold. A plastic material which has hardened in it and which has been emptied out may be considered a simple cast. Let us imagine that the smooth interior surface of the cup becomes successively more irregular in form and that the cast is emptied out with increasing difficulty until finally it can not be removed. Such a difficulty is met by complicating the mold, by dividing it into a number of pieces each of which is sufficiently simple in form to be removed without difficulty from the cast. Again let us imagine that this complex mold and cast have so increased in size and weight as to prevent turning and emptying. Such a condition would evidently prevent filling the mold as a receptacle and require unusual methods of casting. Such a cast might well be made hollow to economize in materials and to relieve the foundations from unnecessary loading.

The Fountain of Time with nearly 100 figures in a continuous form 120 ft. long, 18 ft. high and 14 ft. wide required a mold too large and too complicated to be filled by usual methods and formed a cast too large to be made solid.

The mold, which was made of plaster of paris heavily reinforced with jute fiber and 2 in. iron pipe, was divided horizontally into 30-in. courses. It was built from bottom to top and from station to station. The bottom course rested upon a timber which was fastened to the base below the feet of the figures in the same position relative to the figures that the

top edge of the concrete base would occupy. The timber so formed the first course of the mold that it fitted onto the top edge of the concrete base, was kept in alignment and supplied by it. At each station there was a zone the height of the model and one inch wide where the molds lapped. This was done in order that after the first section had been poured each concrete cast would act as a guide for the assembly of the next section of mold and as a bulkhead for one end while a temporary bulkhead close the other. Because the group has 255 ft. in girth we thought it wise not

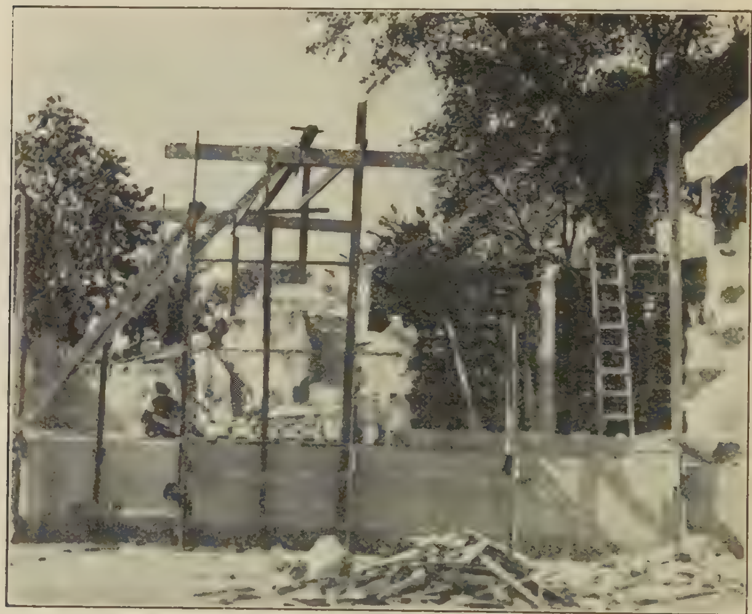


FIG. 2.—PART OF CONTOURS COVERED WITH METAL LATH AND CEMENT MORTAR.

Shows yokes which were built to brace the mold and by which the molds and materials were hoisted into place also the lower course of a mold in place and one of the bridge-like sections which spanned from side to side.

to depend altogether for alignment on the top edge of the base and the vertical jigs but to leave three or four narrow sections for closures in which any slight misalignment could be adjusted. We were indeed pleased when we found that the mold for the last pouring lined up with the first casting, without need of adjustment, nevertheless, were we doing another Fountain of Time we would leave closures and provide for adjustments.

Two particularly interesting features of the mold were the sections across the top extending from side to side in the form of bridges, which were self-sustaining and which supported the surrounding pieces of mold in a construction similar to the masonry vaults of certain Gothic churches.

The other feature was the arrangement of the mold under the figures which projected almost horizontally from the general mass. Before final set had occurred it was necessary to remove these pieces of the mold and to surface the concrete. At the same time if we were obliged to remove the supports from these projecting figures before the concrete had developed considerable strength it would certainly fail. To overcome this difficulty the pieces of the mold were made with the shape of the joints reversed. Ordinarily the joints are made to resist pressure from within, they are interlocking and can only be broken by removing the pieces of the mold in the reverse order to that in which they are made. But these pieces were made so that they could be removed separately, replaced and propped after the concrete had been surface treated. The mold for the Fountain of Time was probably the largest plaster piece mold ever made. It consisted of about 4500 pieces of various sizes. The smallest were about 12 in. across and weighed 25 lb., the largest were about 30 in. by 4 ft. and weighed over 1000 lb.

In preparation for the core which was to establish the thickness of the concrete and keep it in contact with the mold a survey of the model was made and contours were drawn at every foot of elevation. Outside of the model wires were stretched parallel to the center line; from these measurements were taken which were translated into their co-ordinates in order that the work might be laid out from a center line. The contours were sawn from wood and assembled in their proper places. They were covered with metal lath and coat of cement mortar composed of one part portland cement and three parts building sand. The mortar was applied with a pointing trowel and without an attempt to compact it. It was a lean mix and hard to apply but it hardened and formed a very porous base well suited to the work it was intended to do.

It so happened that our engineer was the first man on the job, which disturbed Mr. Taft not a little. It was difficult for him at first to understand what part a civil engineer could have in the work of a studio such as mine on a monument such as his. His difficulty, however, soon departed when he saw the application of modern principles to an old art.

When the core was completed timbers were attached vertically to the base by bolts screwed into sockets provided for that purpose. The timbers were connected to each other at the top by joists. They formed supports against which the mold was braced and being attached to the concrete base were by far superior to supports set in the soft soil which surrounded the fountain. They also served as pole derricks to which we attached rigging and by which we hoisted all the molds and materials.

The concrete was made of Potomac River gravel selected to contain particles varying in color from white to yellow to brown and crushed and arranged in size so that at the distance of one hundred feet the surface of the concrete would appear uniform in color and texture. The general hue of the concrete is yellow red of bright value and weak chroma (YR7/2) as noted by the Munsell System. This is called a 100 ft. concrete because

the particles on the surface blend to a uniform color and texture at that distance. Concretes may be designed to resolve to hue at any distance at 25 ft. for interiors, at 50 ft. or at 1000 ft. for bridges. In order that the concrete might completely fill so complicated a mold it was necessary to mix it very soft. In order that it might not shrink away from the dome-like surface of the mold it was necessary to mix it very stiff. This difficulty was overcome by bringing about a change in consistency while the concrete was in the mold. The core was so constructed that it would extract the excess water but at the same time leave sufficient for

FIG. 3.—PART OF THE FINISHED STATUE.

Shows in one view nearly all the peculiar features of the work, the core, the molds, the yokes, the casts, the vertical jigs, the structural base, and the finished casts.

the hydration of the cement. Although the most important parts of the work, such as heads and arms were at the top of the molds, the most difficult position to fill the concrete showed no tendency to shrink away from the mold owing to the extreme density developed when the excess water was extracted.

Periodically we do something in the surface treatment of concrete which seems to be interesting and encouraging and which you kindly write me to describe. On these occasions I always bring to you the same message, namely; that concrete has in itself and of its own nature properties, which is skillfully developed and controlled, will make it the most satisfactory architectural and artistic medium ever known.

Correction Data for Comparative Test Results from Field Specimens.

By G. W. Hutchinson.*

It has been realized for some time that there is a need for data to allow an intelligent comparison of compressive tests of field concrete with that made in the laboratory.

On account of the nature and design of field structures, it is not always possible and most of the time impracticable to obtain the proper specimens in the field for direct comparisons with laboratory results without correction for certain variables.

In order that the laboratory may obtain the best results from field data, it is necessary to eliminate as many as possible of the variables which exist between the two methods of procedure; first with reference to test specimen, either made from the freshly mixed concrete in the field or from the mass after it has hardened; and second with reference to the standard test specimen made under laboratory conditions.

One of the most important of these variables concerning general practice is the size and shape of the test specimen. In the case of freshly mixed concrete, it is possible to make the field specimen of the exact size as the laboratory cylinder, but when testing the mass by drilling the specimens after the concrete has hardened, it is not practicable to accomplish the result without uneconomic procedure.

The data presented here is applied principally to the correction necessary in the use of the core drill in highway construction. As the testing of this class of work is becoming more and more important, the need for a standard means of making the correction is apparent.

Outline of Investigation.—In making the investigation it was assumed that comparisons of field strengths would be made with the standard 6 x 12 in. cylinder as recommended by the American Society for Testing Materials, and that the ratio of height to diameter would not be less than one-half or greater than two. The range of tests, however, included specimens slightly exceeding the latter ratio.

The data presented represents a total of over 250 specimens, although over 300 were made. The test results of specimens not included in the tables or figures consist of cylinders having a ratio of height to diameter of less than one-half, which gave such a wide range of values that there was apparently no consistent conclusion to be obtained and the variations were assumed to be due to causes other than the shape of the specimen. On account of the usual field specimen exceeding the height to diameter ratio of one-half, no further attempt was made to establish a point on the curve for the specimens having a ratio less than this.

*Assistant Engineer, North Carolina State Highway Commission, Raleigh, N. C.

The correction curve represents the total of about 250 cylinders having a constant diameter of 6 in. and a height varying from 3 in. to 13 in. in steps of 1 in. Each point on the curve represents the result of from

TABULATION OF TEST RESULTS OF CONCRETE OF DIFFERENT COMPRESSIVE STRENGTHS (lb. per sq. in.) AND SIZES OF SPECIMENS.*

Specimen Number.	Height of Specimens in Inches.											Average Strength of 9 to 13-in. Specimens.
	3	4	5	6	7	8	9	10	11	12	13	
1	2574	1925	1492	....	1229	1129	998	1007	966	1064	991	1005
2	3353	2206	1847	1793	1527	1652	1541	1581	1469	1413	1432	1487
3	4812	3110	2632	2305	2043	2113	2022	2035	1980	1863	1996	1979
4	4652	3762	3135	2739	2431	2391	2360	2281	2163	2278	2257	2268
5	4915	3715	3096	2722	2511	2620	2480	2576	2497	2499	2524	2515
6	5766	4456	3914	3818	3345	3133	3140	3091	3053	3109	2900	3059
7	5825	5123	4142	3763	3674	3683	3624	3533	3654	3479	3429	3544
8	6824	5643	4799	4667	4356	4542	4315	4179	4091	4185	3936	4141
Average	4830	3743	3132	3087	2640	2658	2560	2535	2485	2486	2433	....

* Each result is the average of from two to four specimens.

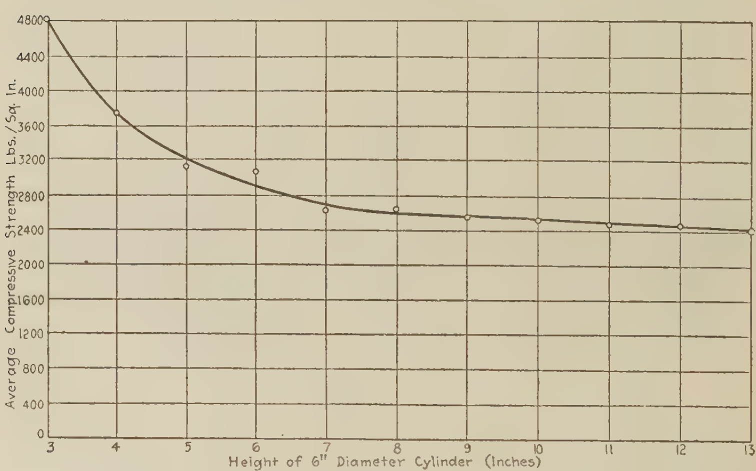


FIG. 1.—DIAGRAMMATIC REPRESENTATION OF RESULTS SHOWN IN ACCOMPANYING TABLE, GIVING RELATION OF COMPRESSIVE STRENGTH TO HEIGHT OF 6-IN. CYLINDERS.

23 to 25 tests. The consistency of the concrete was constant throughout and was considered as that of practical roadway concrete. The strength of the concrete was varied, both by the amount of cement used and by the age of the specimen when tested. The proportions of the mixtures

were varied from 1 : 3 : 6 to 1 : 1½ : 3, and the age from seven days to two months. One complete set containing one specimen of each height was made at one time and each set was made on different days. While there is found to be a slight variation in the correction curve for concrete of different strengths, it is so slight and within the limits of test errors, that it could be considered negligible as far as the use of the average curve when applied to tests of field concrete is concerned.

Each batch of concrete, so far as possible, made two specimens. Sufficient materials were proportioned to obtain the required amount to mold one cylinder 6 x 13 in. This furnished sufficient material to mold one specimen of the 11, 12 and 13 in. heights and in the smaller specimens the same size batch was used to mold one 10 in. and one 2 in. specimen; one 9 in. and one 3 in. specimen, etc. In this way the size of the batch was kept constant and any differences due to mixing were minimized. The concrete was hand mixed on a square metal lined mixing board sloped toward the center to prevent the escape of any water. The cement and fine aggregate were mixed dry in a small hand mixer and then placed on the mixing board and the coarse aggregate and water were added.

All materials used were taken from the storage bins for materials used in making standard concrete by the North Carolina State Highway Commission method of testing. This consists principally of storing fifty bags of one brand of cement in a metal lined storage bin after it has been thoroughly mixed in small units in a concrete mixer. The fine aggregate bin is supplied by drying the materials at one hundred degrees centigrade and mixing small units in a concrete mixer before placing in the bin. The coarse aggregate consists of crushed granite screened by hand through a ⅜ in., ¾ in. and 1½ in. circular opening and then recombining for each batch of concrete in the proportions of 60 percent of material between the ⅜ and ¾ in. screen and 40 percent between the ¾ and 1½ in. screen. Suffiicient materials to complete a given investigation are prepared in advance of the mixing.

The specimens were kept in the molds for twenty-four hours and then stored in a damp closet equipped with humidifiers and a wet and dry recording thermometer. The humidity was recorded as averaging about 95 percent and the dry bulb temperature between 70 and 75 deg. F.

All specimens were tested damp in a Riehle Universal Testing Machine of 200,000 lb. capacity with a spherical bearing block on top.

Discussion.—Fig. 2 is given as a means to secure a direct multiplication factor for use in making a correction of field strengths with reference to the standard laboratory 6 x 12 in. cylinders, when the field specimen is 6½ in. in diameter which is the diameter of the specimen taken by one of the core drills almost universally used in pavement testing.

The individual sets are grouped in classes according to the compressive strength of the average of the specimens from 9 to 13 in. high. These limits are set on account of the small amount of variation between

the test results of the specimens within them. The effect of the compressive strength of the concrete on the general correction data shown in the table is disregarded in plotting the correction curve (Fig. 2).

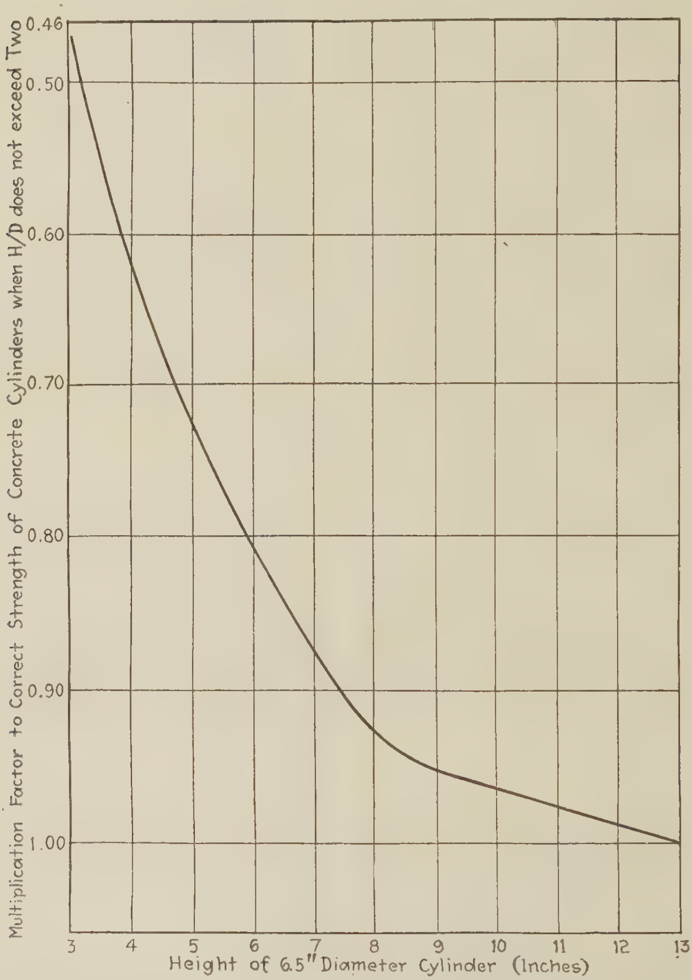


FIG. 2.—CORRECTION CURVE FOR COMPRESSIVE STRENGTH OF CONCRETE FOR VARYING HEIGHT OF 6½-IN. CYLINDERS.

The maximum deviation from the correction curve shown is 6 percent and the average deviation is 1 percent.

It will be noted in Fig. 1 that the correction factor decreases as the height of the specimen increases. The effect on the compressive strength

of the varying sizes of cylinders when the ratio of height to diameter exceeded one was considerably less when it was less than one.

In highway work the usual thicknesses of pavement vary from 4 to 8 in. and it will be seen that, for comparative purposes, the concrete in a 4 in. specimen having a 6 in. diameter would show a compressive strength over 50 percent greater than the same concrete in an 8 in. core of the same diameter.

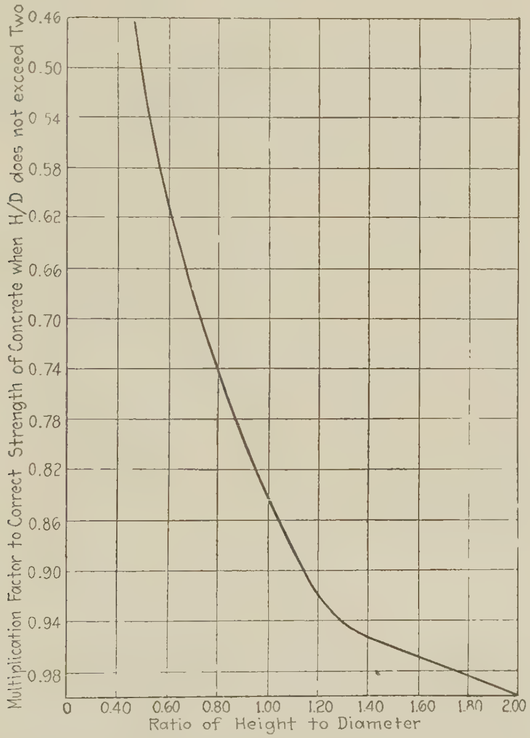


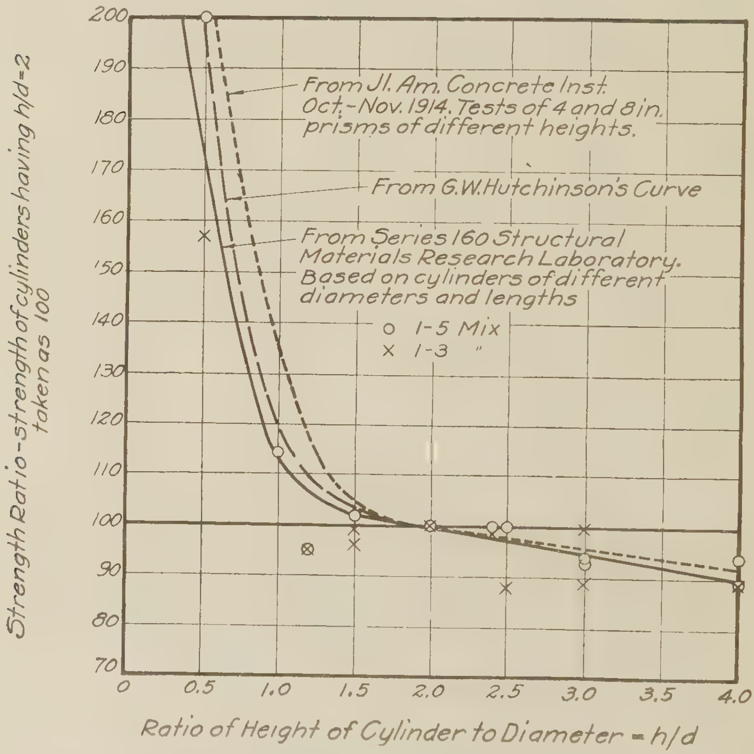
FIG. 3.—CORRECTION CURVE FOR STRENGTH OF VARYING RATIOS OF HEIGHT TO DIAMETER.

Conclusion.—1. It is indicated that the use of a correction factor is necessary for the comparison of the compressive strength of concrete when the ratio of height to diameter of the specimen is varied.

2. A means of making the correction is furnished which is within the practical limits of testing, and applicable to the testing of concrete pavement construction or other field testing when the specimen is cylindrical and the ratio of height to diameter not less than one-half or more than two.

DISCUSSION.

Mr. Abrams. D. A. Abrams.—We seemed to have recognized the need for information of the type presented by Mr. Hutchinson and at about the same time carried out tests along quite similar lines. These tests were made with the general object in view of determining the effect of size and shape of the test specimen on the strength of the concrete.



VARIOUS TESTS ON ROTATION OF HEIGHT OF SPECIMEN TO COMPRESSIVE STRENGTH.

Compression tests were made on concrete cylinders using a constant diameter of 6 in., and varying the height from 3 to 24 in. We also used a constant height of 12 in. and varied the diameter from 5 to 10 in. The details of the tests are given below:

	Diameter—in.	*Length—in.*
(1)	6	3, 6, 9, 12, 18, 24
(2)	3, 4, 5, 6, 8, 10	12

Mr. Abrams.

Mixes 1: 5 and 1: 3 by volume;

Hand-mixed concrete;

Relative consistency 1.10;

Cylinders were stored in a moist room until tested at 28 days;

The values are platted on the attached diagram in terms of the relative strengths as compared with the specimen having a height of two diameters; this value is consdered as 100%, and the other values platted on the basis of their relative strength.

The solid curve is based on our tests—separate points are platted for the 1: 5 and 1: 3 mixes. In general, each point on the curve is based on 10 tests made on different days.

The dotted curve is reproduced from *Journal* Am. Concrete Inst., Oct.-Nov., 1914. Tests were made by Massachusetts Institute, Technical University of Illinois, and University of Wisconsin on 4 by 4- and 8 by 8-in. concrete prisms of different lengths; approximately 1: 2: 4 mix; normal consistency; age at test 3 months. Each value average of 4 tests.

The middle curve is from Mr. Hutchinson's paper platted to the same scale as the others.

There is a very close agreement between our values and those given by Mr. Hutchinson; but in general our values fall somewhat below the 1914 A.C.I. curve; however, the discrepancy is not very great, except for the lower ratios of height to diameter.

Our tests show the following average values:

h/d	*Strength Ratio—Percent*
0.5	170
1.0	115
1.5	103
2.0	100
3.0	95
4.0	90

The concrete strengths for 6 by 12-in. cylinders (which was the size of the cylinders for $h/d=2$ in both the above groups of tests) at 28 days were 1: 5 mix, 2980; 1-3, 4450 lb. per sq. in. The average of all cylinders with $h/d=2$ (sizes ranging from 4 by 8-in. to 10 by 20-in. cyl.) were 2960 and 4540 lb. per sq. in.

The effect of height of specimen appears to vary somewhat with the age of the concrete; 7-day tests gave a greater variation in strength for different heights than the 28-day and 3-month tests. We also observed another relation which we have not been able to explain; that is, large specimens give lower strength than smaller ones of the same concrete. For example, a 10 by 20-in. cylinder (the largest size used) gave lower strengths than 6-by 12-in. or 4 by 8-in. Just where the discrepancy lies we do not know; whether it is in the method of placing the concrete in the form or the manner of applying the load, during the test.

Design and Construction of Stadiums.

Clyde T. Morris.*

Public interest in athletic contests is as old as history. The earliest records show men competing in games of skill and endurance, and their influence on civilization is clearly evident. One of the most important links in the early Greek union was the Olympian Games which were held every four years at Olympia. The first Olympiad was held in the year 776 B. C., and from that time on for over a thousand years they were held regularly and did much to maintain a sense of common Greek interest

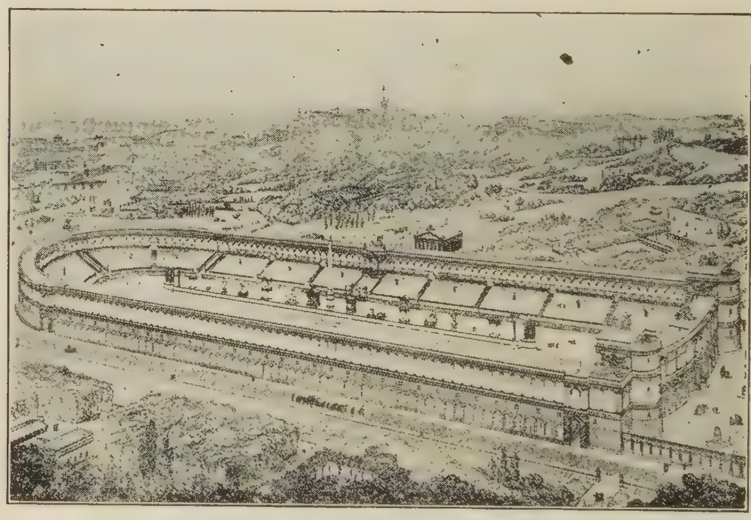


FIG. 1.—CIRCUS OF CALIGULA AND NERO.

which transcended the narrow politics of the several city states and preserved them as a union.

"Stadium" was the name of the race course at Olympia, and the length of this course came to be adopted as the unit of measure for distance by the Greeks and Romans. Its length was 606¾ ft. As the number of spectators increased, the race course was surrounded by a raised bank of seats, and it is this seat bank enclosing the field for the games that we call a stadium.

The greatest structures built by the Romans were for their games. Every Roman city had at least one circus, and Rome herself had several.

*Professor of Structural Engineering, Ohio State University.

The Roman circuses were built primarily for chariot racing, and the length of the course in the Circus Maximus, which is the largest amphitheater of which we have any record, was about 4,000 ft. The length of the building was probably at least 2,500 ft., and it is said to have accommodated

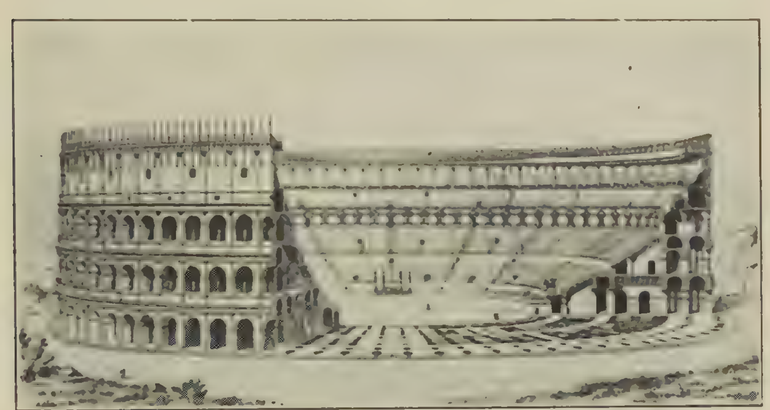


FIG. 2.—THE ROMAN COLOSSEUM.

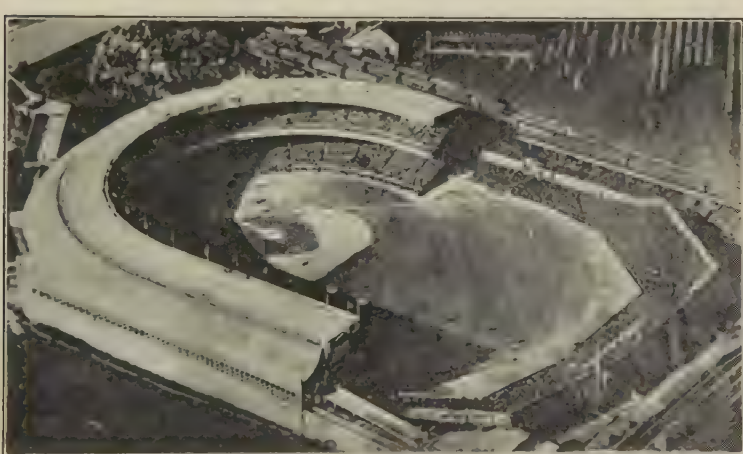


FIG. 3.—THE POLO GROUNDS, NEW YORK.

350,000 spectators, most of whom stood. The nobility only were provided with seats.

Another type of Roman amphitheater was that designed for witnessing gladitorial combats and games requiring a smaller arena. Of these the most famous was the Colosseum in Rome, which was built by the Em-

perors Vespasian and Titus, and was finished about 80 A. D. It is about 620 ft. long, 513 ft. wide and 157 ft. high. The longest diameter of the arena was 287 ft., and it is said to have had seats for 80,000 spectators and standing room for 20,000 more.

The modern American games for which structures of large seating

FIG. 4.—THE TACOMA STADIUM.

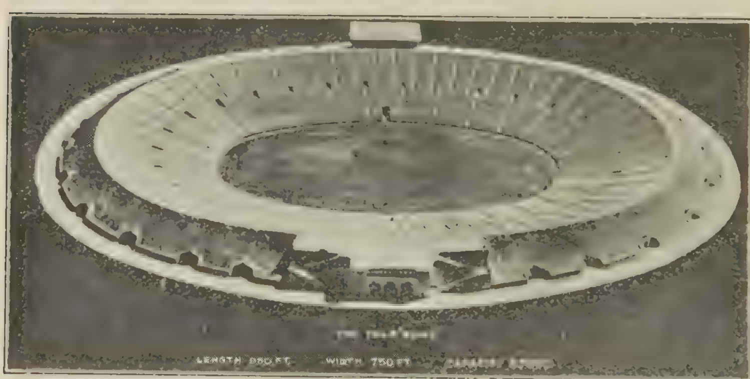


FIG. 5.—THE YALE BOWL.

capacity are required are racing, baseball, and more recently, intercollegiate football.

Race course and baseball grand stands have usually been of relatively temporary construction, using timber seats on structural steel supports, but within the past fifteen years a large number of grand stands of more permanent construction have been built.

The first stadium in this country, of a permanent nature, for intercollegiate games, was built at Harvard University about twenty years ago.

Since that time many have been built, and within the past five years a veritable epidemic has spread over the country.

There are three types of stadiums, and the selection for a given case depends upon local conditions and the uses to which the structure is to be put.

The hillside type is the natural and of course the cheapest type, where a location is available that can be adapted to this use. The Tacoma Stadium is perhaps the best example of this. A curving hillside forming a natural amphitheater made the cost of construction very low.

The second type is built by excavating for the playing field and the lower half of the seats and banking the earth around the excavation, on which the balance of the seats are placed. The Yale Bowl is the outstanding example of this type of construction. It can only be used where adequate drainage can be secured, but if the conditions are right it is

FIG. 6.—THE STADIUM AT OHIO STATE UNIVERSITY.

comparatively cheap. This type accommodates only one sport, football. There is no room for the necessary straight tracks for foot races. The new stadium now under construction at the University of Illinois will have the lower twenty rows of seats built within the excavation for the playing field and the balance on a concrete and steel superstructure.

The third type has the entire seating capacity supported above the ground level on structural work, and is the most expensive type to build. Harvard, Princeton and the new stadium at the Ohio State University are examples of this type.

The location of the stadium at the Ohio State University is shown in Fig. 7. It is built on the low ground between the main group of university buildings and the Olentangy River. The axis lies nearly north and south, with the open end to the south. The flood of 1913 covered the whole area west of the drive shown along the rear of the university buildings, and other floods in the past have come above the elevation of the playing field on an average of about once in three years, but since the completion of the river improvement work in the city of Columbus, the

maximum elevation of high water has been about 2 ft. below the playing field level. This occurred last April (1922), when river gagings show that more water passed through the city than at any other time since 1913. This volume of water, before the river improvements were made, would have covered the playing field about 3 ft. deep. Work on the dike and boulevard along the river bank will be started in the near future, and

FIG. 7.—THE CAMPUS, OHIO STATE UNIVERSITY.

this will effectively protect the site. From this description it is evident that only the third type of structure, that entirely above ground, could be built here.

Before the design was completed and the contract let, the location chosen was investigated as to foundation conditions by drilling eighteen test wells, four of which went to rock, 57 ft. below. It was found that an excellent quality of boulder gravel could be secured as a foundation near the surface on the east side, and at a depth of from 10 to 14 ft. on

the west. The structure was founded on this material with a dead load unit pressure of 2900 lb. per sq. ft.

What we have chosen to call the "Ohio Plan" consists of an open end horseshoe with bowed sides and a double deck. The open end with the

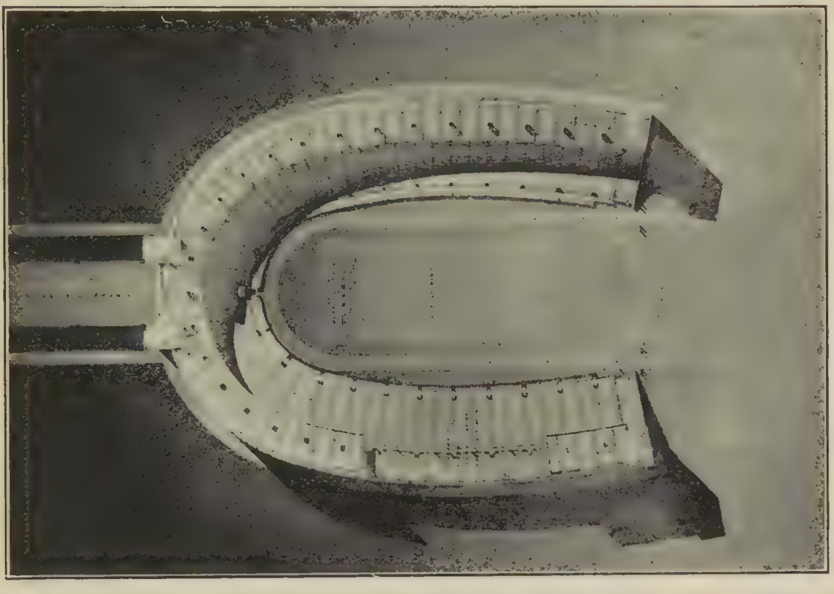
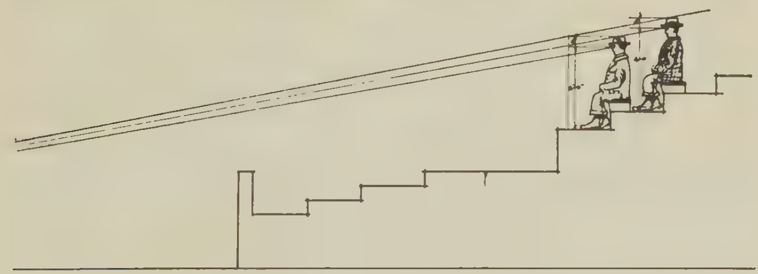


FIG. 8.—THE OHIO PLAN.



SIGHT LINE DIAGRAM ——— OHIO STADIUM

FIG. 9.—SIGHT LINE DIAGRAM, OHIO STADIUM.

straightaways running beyond the structure, make it possible to hold track meets as well as football in the stadium. The bowed sides give the double advantage of a better angle of vision and a comprehensive view of the entire crowd. The inspirational effect of a great crowd of people in holiday spirit is greatly enhanced by the curving of the sides.

The double deck is not new in baseball grand stands, but has never before been used in a college stadium. The effect is to bring about one-third of the seats about 50 ft. closer to the playing field without mate-

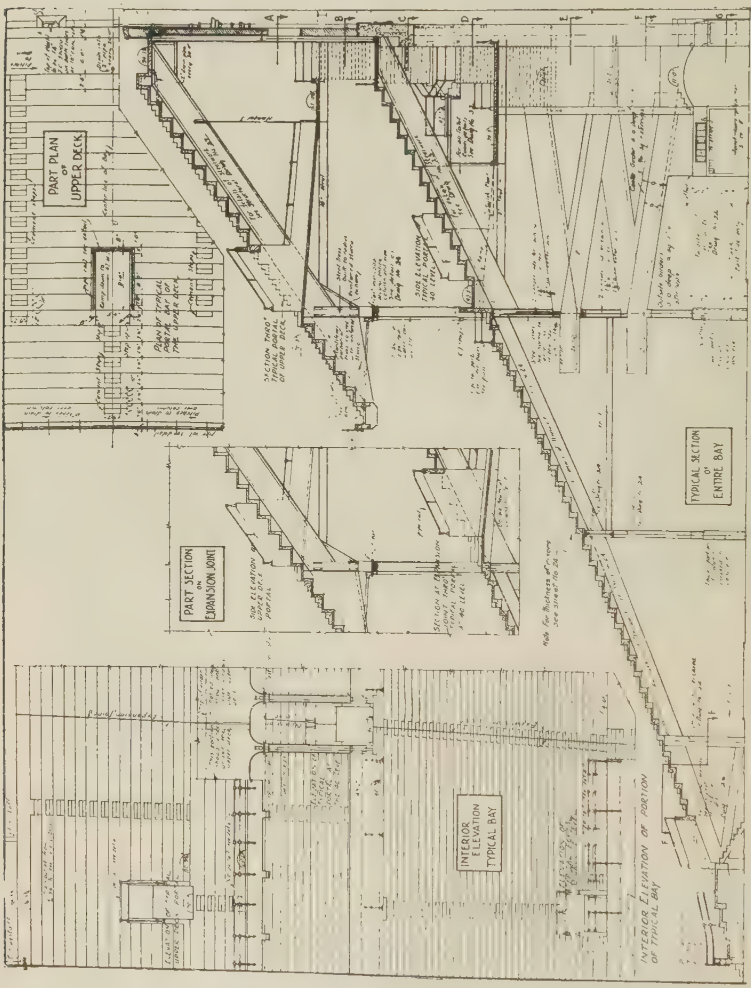


FIG. 10.—TYPICAL SECTION OF ENGIRE BAY.

rially increasing the height of the structure, and it also provides shelter from the weather for about one-third of the seats.

The plan of the stadium is 704 ft. by 597 ft. and encloses an arena 556 ft. by 294 ft. The playing field is surrounded by a quarter-mile cinder track with straightaways for the dashes extending beyond the south end of the structure.

The field is underlaid with a herringbone system of farm drain tile, 18 in. below the surface. The upper 2 ft. of the soil is a clay loam which is very fertile, being the alluvial top soil of the valley. The gridiron is crowned 12 in., which gives additional drainage.

The vertical curve of the seat banks was determined by drawing sight lines from each seat, over the head of the person immediately in front, such that all persons can see the center of the running track. The method is shown in Fig. 9.

The future development of the structure calls for the closing of the arch openings with steel sash and glass, in order that the space beneath the seats may be used for indoor track athletics, basketball, handball and similar intra-mural activities, as well as various kinds of exhibitions, such

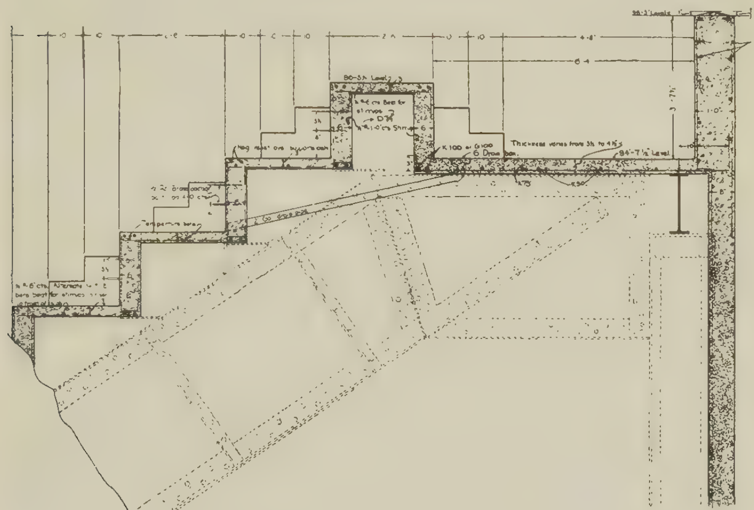


FIG. 11.—TYPICAL SEAT RISERS.

as horse shows, machinery exhibits, student carnivals, etc. On one side a sixth of a mile running track and a 100 yd. straight away are provided for.

These activities required that the space beneath the seats be kept as free from obstructions as possible. The column spacing was made wide and the bracing kept high. These features increased the cost considerably and made the use of structural steel more economical than a structure entirely of reinforced-concrete.

Another reason for the use of a structural steel frame was the the possibility of winter erection. The foundations were completed by the middle of November, 1921, and the structural steel frame was ready for the concrete by April 1, 1922. If a purely reinforced-concrete frame had been used, it would have required at least another year for the completion of the stadium.

The structural steel frame consisting of heavy steel columns and girders, is not exposed to the outside weather at any point. The columns supporting the upper deck and all other outside steel work is encased in

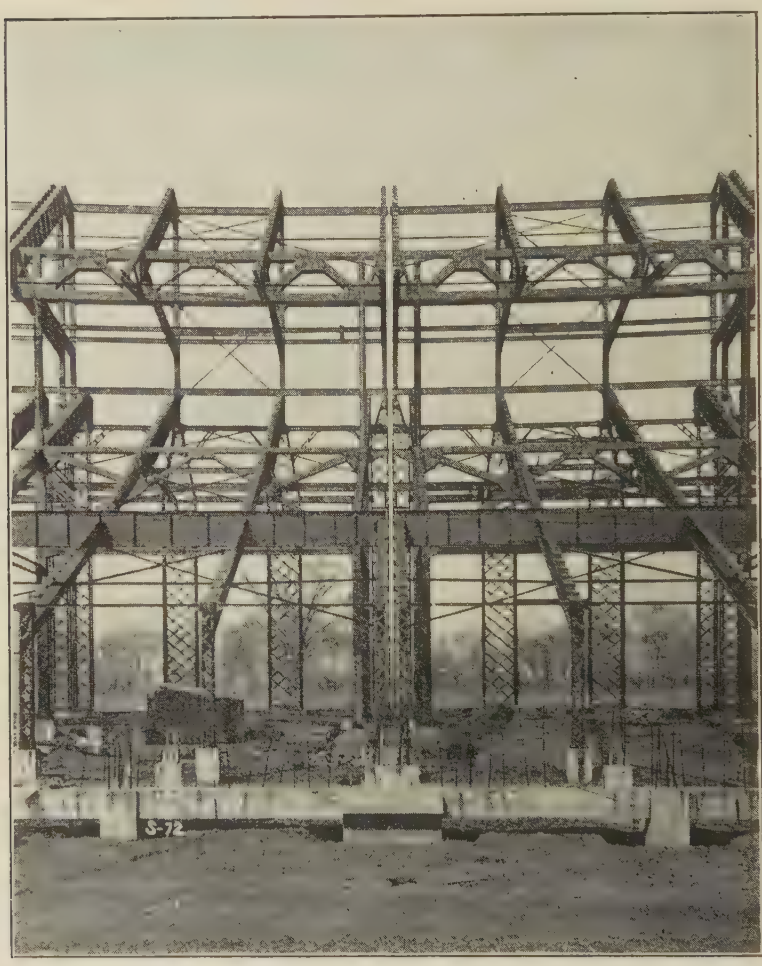


FIG. 12.—STEEL FRAME AT EXPANSION JOINT.

concrete. The interior steel work will require painting about once in six years. A typical cross section and elevations are shown in Fig. 10.

The seat risers were calculated as simple rectangular beams to carry the seat load from steel girder to girder. (About 19 ft.) The risers were supported on the girders by bent plate chairs.

The steel frame was designed to carry the weight of the hoisting engines and travellers used in placing the concrete as well as the forms. The outside columns were made of four angles double latticed in the form of a rectangle 3 ft. by 6 ft. in cross section. The forms for these columns were held in line by the steel work and when finished, formed a solid column 3½ ft. by 7 ft.

Before starting the design the writer visited most of the structures of a similar nature in the East, and made a study of provisions for taking care of expansion and contraction, and the effects of these on the structures. The evidence thus secured convinced him that no reasonable amount of reinforcing would prevent shrinkage cracks in a structure over 150 ft. long, which is exposed to weather conditions such as ours. The structure was therefore designed in radial units 60 ft. long on the outside. Twin columns were provided at each joint so that the structure is completely cut through and no sliding of one part on another is depended upon.

This division into sections also proved to be advantageous in providing

FIG. 13.—EXPANSION JOINT.

convenient locations for construction joints. To prevent leakage through the joints, the abutting sections are connected by sheet lead strips bent into a U-shape and filled with a pre-molded asphaltic joint filler. As soon as the cooler weather in the fall came, the working of the expansion joints could be seen. Of course the shrinkage of the concrete in curing also contributed to the movement. Fig. 13 shows the opening in one of the joints on Jan. 17. The asphalt is about ¾-in. in thickness and the opening nearly ⅛-in.

No provision was made for expansion radially except in the design of the columns. These were so high without transverse supports that the expansion and contraction is easily taken care of by bending of the columns. The stresses so induced were taken into account in their design.

The expansion joints located in the closed end of the U where the radius of curvature is short show little or no opening. This is accounted for by the fact that the radial contraction pulls the columns inward, and thus the arc is shortened a proportional amount and renders the action of the joints less pronounced.

At the north or closed end of the stadium is provided the main en

trance with ticket offices, etc. This is featured by a half dome 70 ft. in diameter and 85 ft. high, over which runs the seat bank of the upper deck, This dome consists of ribs radiating from the crown and stayed by four horizontal ribs, thus dividing the dome into 45 spherical rectangles. These ribs support coffers which were pre-cast and set in place after the ribs were completed. The middle area of each coffer is inlaid with blue tile with a terra cotta rosette and electric light in the center.

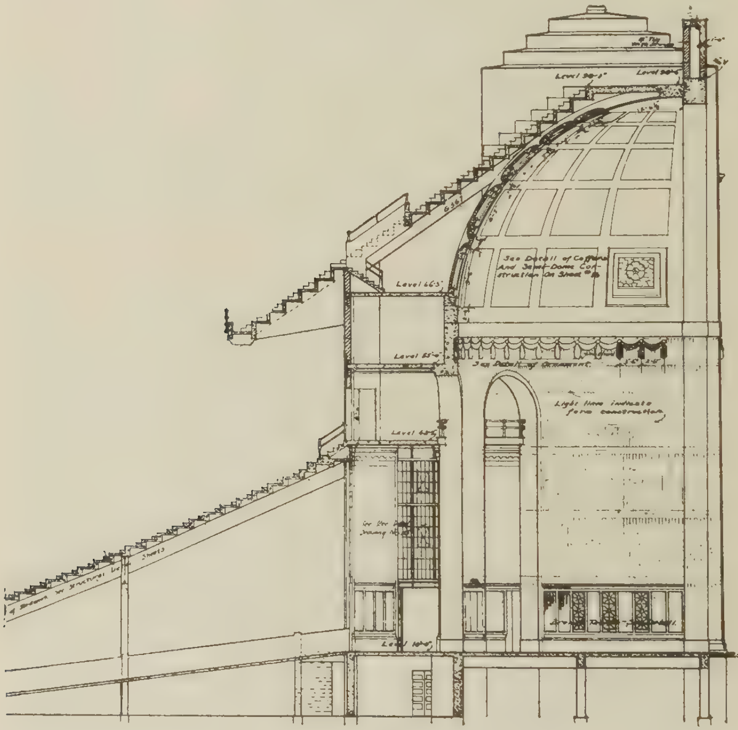


FIG. 14.—SECTION THROUGH DOME.

The ribs were figured as half arches, the horizontal thrust at the crown being taken by a horizontal girder running from tower to tower and forming the promenade over the dome.

At the south end of the U are two towers in which are located the athletic offices, training quarters, locker rooms, shower rooms, etc. These towers were built mainly for architectural effect, but they are made use of very effectively. There are six floors in each tower. The quarters for the freshmen teams are in the southwest tower and for the varsity teams in the southeast tower. During games the freshmen quarters are given to the visiting team.

The seats are made of wood strips, 1¾ in. by 3 in., supported above the concrete on wood blocks, and are uniformly 17 in. high. These are secured to the concrete by brass bolts set in the risers when they were poured. The construction is shown in Fig. 17.

Construction.—A spur from the Hocking Valley Ry. to the university, runs 450 ft. north of the stadium, and from this, tracks were laid around the east side, for the delivery of materials, and back clear around the U between the outside and the second row of columns. Locomotive cranes on these tracks handled the excavation and placed the concrete of the foundations. The concrete was delivered from the central mixing plant in

FIG. 15.—BACK OF DOME.

yard buckets on industrial railway cars pulled by gasoline locomotives. The structural steel work was also erected by locomotive crane.

All concrete was mixed in a central plant located about midway on the east side of the structure. The sand, stone and cement were elevated into bins above the charging floor and fed by gravity into the hopper as required.

The sand and stone were measured by volume and the cement, which was delivered in bulk, was weighed in a box on a platform scale under the chute.—Fig. 19.

The concrete for the seat banks was hoisted in the buckets from the industrial cars, to a hopper, and delivered through short chutes to the desired location. These chutes had gates in the bottom every 4 ft. and

FIG. 16.—NORTH ENTRANCE OHIO STADIUM.

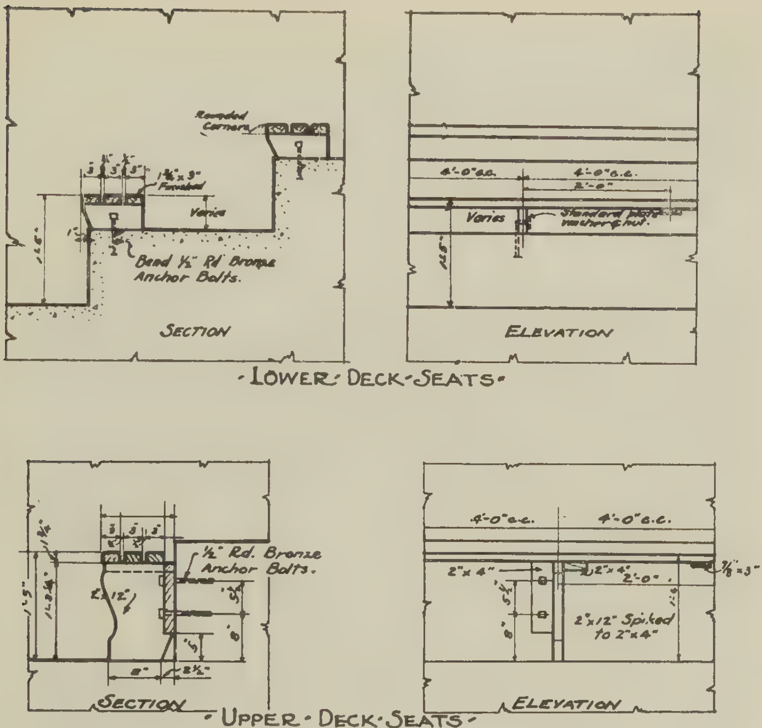


FIG. 17.—UPPER DECK SEATS.

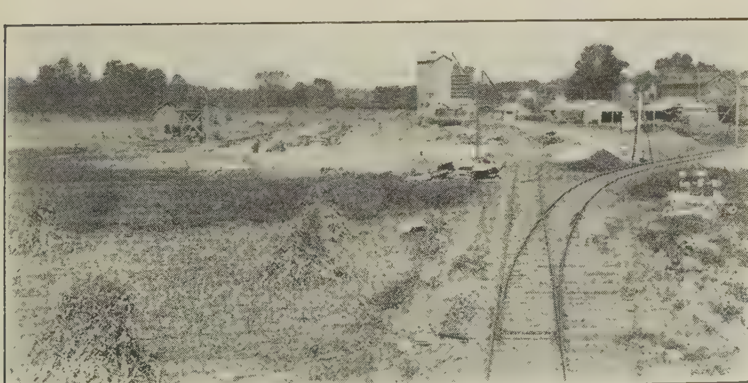


FIG. 18.—CONSTRUCTION PLANT.

were mounted on tracks at the top and bottom so that they could be moved longitudinally as necessary.

After the structural steel work was erected, four travellers were built on the upper deck as shown in Fig. 20. These were very efficient and handled all forms and concrete for the seat banks.

No effort was made to obliterate the form marks. In the architectural design, the location and direction of all joints in the forms of exposed portions were shown, and so arranged as to give the desired effect. As concrete is generally known to be a molded material, it was believed that the

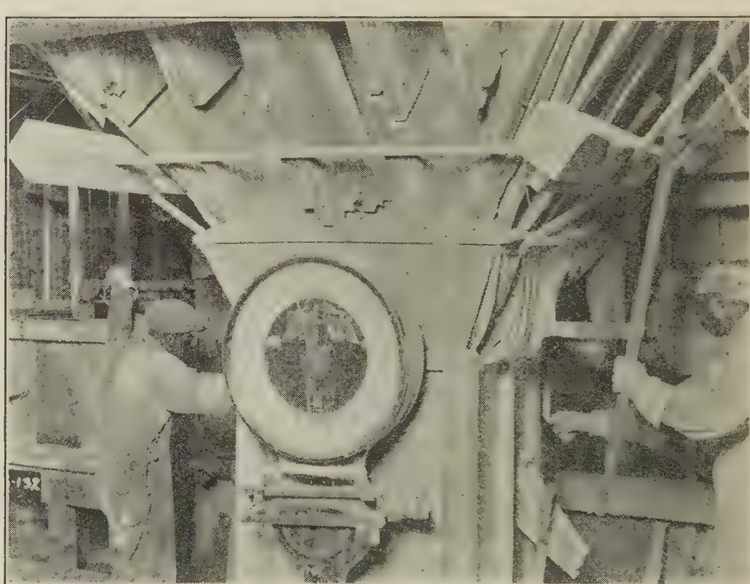


FIG. 19.—SCALES FOR WEIGHING CEMENT.

marks of the molds is a frank expression of the material. The results obtained in the field are very gratifying.

Access to the upper part of the lower deck and to the upper deck is provided by a series of six ramps on each side. The railing girders of these are designed to carry the loads between the lines of columns. The inner ends of the ramps are suspended from the trusses carrying the seat banks. The pitch of the ramps is about 15%. Under each ramp on the ground is located a toilet room, and immediately above these on the 40 ft. level are others. This gives a total of 24 toilet rooms distributed around the structure.

Costs.—The total cost of the structure proper was about $1,370,000. There are 62,110 numbered seats in the structure which gives a cost per

FIG. 20.—CONCRETING SEAT BANK OF THE OHIO STADIUM

seat of about $22. If the cost of the south towers, the dome at the north end and other architectural features which do not add to the seating capacity be deducted, the cost of the seat banks proper was about $18.50 per seat.

The following table gives some of the quantities of material used and the unit costs in place, exclusive of overhead charges. The overhead charges embracing superintendence, fuel, temporary structures and incidentals, amounted to about 11%. The cost of the architectural and engineering work including design and superintendence was about 4%:

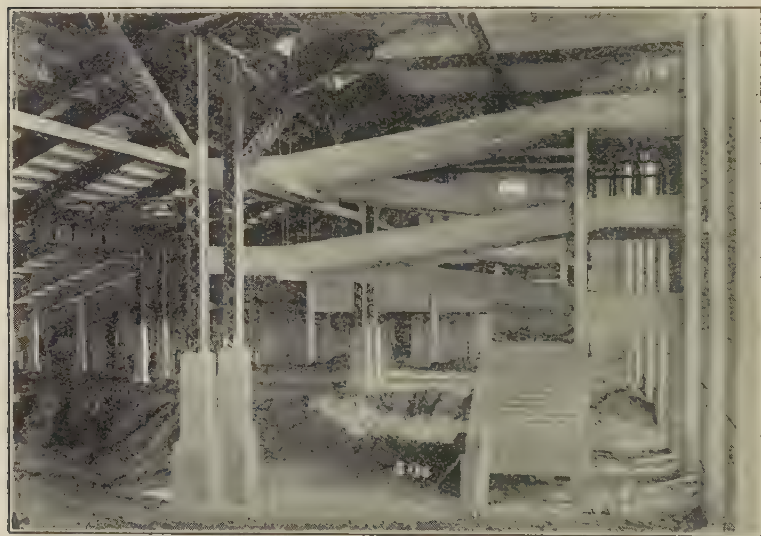


FIG. 21.—THE RAMPS.

Excavation, 14,200 cu. yd.	$0.93
Foundation forms, 128,700 sq. ft.	.13
Foundation concrete, 5,415 cu. yd.	6.10
Superstructure forms, 1,482,000 sq. ft.	.22
Superstructure concrete, 25,500 cu. yd.	8.10
Reinforcing steel, 1,326 tons	63.55
Structural steel, 4,100 tons	75.40
Expansion joints, 13,670 sq. ft.	.41

The architectural work was done by Howard Dwight Smith and the engineering and superintendence were in charge of the writer. The contractor was the E. H. Latham Co., of Columbus, Ohio.

Franklin Field Stadium of the University of Pennsylvania.

By H. T. Campion.*

The new stadium of the University of Pennsylvania is located at Franklin Field, which is a part of the university grounds. On the west end of the field there is a gymnasium, a beautiful and efficient building designed by Day & Klauder in 1903—and at the time the gymnasium was built, wood stands were constructed on the north, east and west sides of the field, and these, with certain temporary stands, had a seating capacity of about 30,000. These stands enclosed a quarter-mile track, a 220-yd. straightaway, baseball diamond and the football field.

The location of Franklin Field, in West Philadelphia, while close to the university activities, has certain very definite handicaps—transportation facilities are inadequate, with little likelihood of improvement in the near future, and the area of the field is limited by surrounding streets, but notwithstanding these definite limitations, the fact that the running track which was there, on which many records have been made, and that it takes years to build a good track, and further that all the facilities for inter-collegiate events were at hand, and had been for some time, controlled the decision of the Athletic Council and the trustees of the University of Pennsylvania to build the new stadium on the old field. The decision was not a hasty one and was reached only after several years of investigation of other possibilities.

The location of the gymnasium at the west end of the field was not much of a factor in reaching the decision; in fact, the gymnasium location was only another limitation to the seating capacity of the new stadium.

With the location problem settled, the engineers, Gavin Hadden, of New York, and H. T. Campion, of Philadelphia, were assigned the task of getting the greatest number of seats at the least cost on the limited property, and of preserving the ¼-mile and 220-yd. straightaway track.

The permanent stands, which seat 35,700, are of concrete construction and the temporary stands are wood seats on easily stored collapsible steel supports, each part is plainly marked for taking down, storing and assembling. The Wayne Iron Works patent stand was used for all temporary seats and supports, except for the high supports under the west stand. Timber towers strongly braced and tied were used here.

The structure for permanent stands was built entirely of reinforced-concrete, although bids were received for making the principal members of steel sections. The successful contractor, the Turner Construction Co., were able to do the work at a lower price in reinforced-concrete, and to guarantee an earlier time of completion, and it is not out of place here to say that the Turner Construction Co. not only made better time than they promised, but lived up to their reputation for performing most excellent work.

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*Vice-President, McClellan & Junkersfeld, Inc., New York City.

The soil conditions were not good—rock was found not less than 40 ft. below grade and an old fill of bad material covered the site; this fill was 12 ft. deep on the west end and 42 ft. on the east. On account of the nature of the fill a floated foundation entailed great risk of unequal settlement and bad cracks. An open specification for concrete piles was written, and the Raymond Pile Co. was the successful bidder, principally on the time element. Their work was done in record time and so far no serious settlements have occurred. The tops of the piles were doweled and tied together by reinforced-concrete beams in each direction.

Almost the entire structure under the deck is useful, and contains, in addition to toilet rooms and lavatories, two complete training and locker room facilities for competing teams, and a third team room for other activities, seven squash courts, a large room for rowing practice, a 100-yd. rifle range, office space, ticket booths and ample storage room for the temporary stands.

City streets were at the north and south side of the field and at the east a street was planned, though not opened, and east of this proposed street was the Pennsylvania R. R. right-of-way with tracks much below the street level.

As a first step the city of Philadelphia by ordinance permitted the arcading of the sidewalks of north and south boundary streets, and by the consent of the Department of Public Works, the use of the proposed street at the east end of the field, which was on the property of the University.

Mr. Hadden made a number of studies of seating arrangements, all of which indicated that it would be possible to have about 50,000 seats in the combined permanent and temporary stands, and as his work progressed, the soil condition was investigated and a number of borings made.

Day & Klauder, of Philadelphia, were retained as consulting architects. This firm had designed the gymnasium, and Mr. Klauder was, and is, one of the architects of the Archeological Museum to the south of the stadium. The design of the exterior of the stadium, which is a series of magnificent brick arches strongly Italian, was much influenced by the proximity of the beautiful museum.

A controlling factor in the general design of the structure was the time limitation. The work could not be started until after the spring relays on May 4, 1922, and the entire seating capacity was required for the Army and Navy game. The fact was never lost sight of as the design progressed.

Mr. Hadden's work on seating and visibility was complicated by the requirement that the track events should be visible from any seat in the permanent stands, and that the addition of the temporary stands should make every seat, in both the permanent and temporary stands, a good seat for visibility of the football field. The track set the limits, on the field side, for the permanent stands; and the temporary stands covered the track on the two sides and the east end of the field and are banked against the gymnasium on the west end.

The seating deck is of reinforced-concrete in step form, with frequent expansion joints and supplied with drainage gutter. Cast-iron brackets oı standards are bolted to the risers on the ,deck at about 4 ft. centers. These support cypress seat strips, the seats are 10 in. wide without backs and in general about 25 in. back to back. They are raised above the concrete treads, by the brackets, far enough to give toe room for the occupant of the next higher seat. The seats vary in height from 18 in. at the bottom row to 19½ in. at the top, and each seat gives the spectator good visibility in both the permanent and temporary stands for all parts of the football field. When the temporary stands are removed all the occupants of the permanent stands will have ample view of the track events. This solution of a difficult problem is entirely due to the study and work of Gaven Hadden.

The area covered by the permanent stands is..	123,640 sq. ft.
and by the temporary stands	47,230 " "
the field enclosed contains	123,730 " "
or a total of	294,600 sq. ft.
The capacity of the permanent stands is	35,700 seats
and of the temporary stands	15,300 "
a total of	51,000 seats

The costs were as follows:

	Field Costs Contracts & Extras	Overhead Engineering Architect & Supervision	Totals
	Contracts and Extras	Supervision	Totals
Permanent stands	$655,583.43	$76,189.88	$731,773.31
Temporary stands	59,638.37	6,930.09	66,569.36
Totals	$715,331.80	$83,120.87	$798,342.67

Expressed in unit costs the permanent structure, cost $5.919 per sq. ft. or $20.498 per seat, temporary stands $1.410 per sq. ft. or $4.351 per seat. An average for the total is $4.672 per sq. ft. and $15.654 per seat.

These prices cover so much more than the mere seating capacity of a stadium that comparison with the costs of other stadiums are difficult; but it must not be forgotten that they include all the interior facilities, an expensive brick arcade made necessary by the character and architectural treatment of buildings adjacent to the stadium, and a concrete pile foundation, usually unnecessary. Omitting the excess costs involved in these items, the price per seat would probably have averaged little more than $11 per seat.

Credit is due the Turner Construction Co. and their sub-contractors for the efficient work and its rapid progress, and for the careful and helpful supervision the credit should be given to Maj. Wm. H. Gravell, of Mr. Campion's office, and to Percy H. Wilson, the engineer in charge of the work for Mr. Hadden and Mr. Campion.

University of Kansas Stadium.

By C. C. Williams.*

The stadium at the University of Kansas was erected as a memorial to the students and alumni who lost their lives in the World War. The architecture is of the memorial style throughout, with straight lines and simplicity in outline as characteristic. Plain tablets crest the towers and constitute the chief features of relief.

Owing to the limited funds available, economy of design had to be given proper consideration. The writer's instructions were to design a stadium, field and all accessories which should not exceed $500,000, and which would meet the needs of the University's athletics for present and for the future so far as they could be predicted with any degree of certainty. The contractor's price for the job complete was approximately $460,000, hence, the design met the instructions so far as cost was concerned. The experience thus far indicates also that it will prove adequate for many years in the future, and with a definite and feasible scheme of enlargement provided, should the future demand more than the present structure, it seems that the future is properly cared for also.

It was required that the structure should accommodiate the football field, a quarter mile track with a 220-yd. straight-away and the baseball field (temporarily).

General Description.—The Kansas stadium is a U-shaped structure consisting of two straight sides and a complete semi-circle at the ends, the over-all dimensions being approximately 632 by 464 ft. and 47 ft. high to the top of the parapet wall at the back. It lies on a north and south axis, centering on a broad paved street which leads to the entrance, with a similar paved street leading to either side. At the sides of the structure is the parking space—about 10 acres—for autos.

The full circular curve was adopted for the closed end because of appearance and because of the better accommodation of the running track.

Some consideration was given to placing the structure so that the football field would be at right angles to the sun's rays at 3 p. m. on Nov. 1, but it was found that the general placement was so marred with respect to topography and other structures that the advantage from such a position seemed to be outweighed by considerations of appearance.

A design which involved placing the structure in the ground was considered, but because of drainage difficulties, inferior ventilation, and other objections, this plan was abandoned. The type selected was of the grandstand character entirely above ground. After the plans were complete for this structure an alternate plan involving the feature of a sunken field and placing the masonry directly on earth slopes was proposed by an alumnus who is an eminent structural engineer. The econ-

*Professor of Civil Engineering, University of Illinois.

omies claimed for this alternate plan were conjectural and the defects definite, hence, it was abandoned by the Memorial Corporation Board, who had the matter in charge.

In appearance the back of the stadium resembles that of Harvard stadium, or its prototype, the Coliseum at Rome, having an upper and lower tier of arches, except that in the Kansas structure, the upper arches were blanked with a curtain wall in order to conceal the skeleton of structural members inside the outer wall. Indeed so effectively is this concealment effected that only the arched openings below appear in the distant view of the structure.

Entrance to the seats is made through these archways, stairs leading directly up stairs to the centers of gravity of the seat sections. This, incidentally, was the scheme of entrance to the Coliseum, for the writer observed the old Roman numerals of seat sections still discernible above the arch ways. The advantages of this mode of entrance are so obvious and the arrangement has been so generally adopted that discussion is superfluous.

Two low towers stand at the entrance and a similar low tower forms the end feature of each prong of the U. These towers are subdued and do not stand out conspicuously from the mass of the entire stadium, the idea being to treat the entire mass as a unit.

A wide entrance to the field is provided at the main gateway at the curved end to permit a parade headed by the band to march directly on to the field in the event of a demonstration or celebration.

Investigation of lines of sight to the various parts of the field from seats farthest removed revealed entirely unobstructed vision, hence it was believed that the advantage of curved sides was psychological rather than real in that they permit the spectator to have a better view of the crowd. Moreover, some objection exists to curved sides in that a distorted view of the field results from the fact that the spectator does not look directly along the yard lines and hence he is likely to obtain an incorrect impression of a play. The increased cost of curved sides also weighed heavily in inclining our choice to the straight sides. The seat banks are curved vertically so as to give equally unobstructed vision for all seats to the side and to the center of the field.

Design Data.—Determining the proper capacity for design was the first question to which the writer addressed his investigations. The maximum at any game on record was 12,500. The Universities of Michigan, Illinois and Wisconsin had record crowds of 20,000 to 26,000. Hard roads were under construction to Kansas City, Leavenworth and Topeka, hence, a greatly increased attendance from those cities might be expected. The present attendance at the University of Kansas is about 4000, while that at the institutions mentioned above is 8000 to 9000. They are situated in many respects similar to the University of Kansas but represent about 15 or 20 years more of development. After duly weighing the pertinent information that was available 30,000 was the capacity aimed at, although exigencies of design placed the actual capacity at 32,000.

Borings were made over the site which revealed a stratum of clay at a depth suitable for the foundation. The footings were proportioned with a view to avoiding uneven settlement by using Schneider's formula $A = \frac{D}{Br}$, where A is the area of any footing, subjected to a dead-load D, B the bearing capacity of the soil, and r the ratio of dead to the total load on the footing where this ratio is maximum.

The live-load including impact was taken at 100 lb. per sq. ft. of horizontal projection, observations which were made having indicated this to be the proper loading.

The design followed the specifications of the Joint Committee in general. Kaw River sand and Oread limestone were natively available at Lawrence, both of which are very satisfactory concrete materials.

The question as to the admissibility of re-rolled steel as reinforcement arose. The writer, with the co-operation of Mr. Joseph Wertheimer, Assistant Professor of Metallurgy, made a study of steel re-rolled from steel rails that was on the market, with the result that the specifications were drawn so as to admit this material.

These tests revealed a much greater variation in the carbon content than the manufacturer's statement indicated, while on the other hand, the ductility was greater than the manufacturer's statement showed. The ductility ranged from 18.0 to 26.5% elongation for the standard 2-in. specimen, the yield point from 54,000 to 67,900 lb. per sq. in. and the ultimate strength from 86,600 to 118,800 lb. per sq. in. It was decided, therefore, that based on uniformity and strength, bids should be received admitting re-rolled steel in the event that the contractor wished to use this material. As a matter of fact, however, re-rolled steel was not used but new billet steel was used throughout.

The reinforcement consisted of deformed bars spaced in the ordinary manner and hooked at the ends where necessary to provide for deficient imbedment, and of a wire fabric in the deck slabs, which supplemented the bar reinforcement.

Because of the more ready adaptability of reinforced-concrete girders as compared with steel and because of the greater cost of steel due to the remoteness from the steel producing centers, reinforced concrete was used throughout, instead of steel framework as at Harvard and Ohio.

Expansion Joints.—Expansion joints transverse to the structure and separating the sections entirely, were placed every 97.5 ft., the portion between two expansion joints constituting a seating section. It was provided that expansion and contraction transversely should be taken care of by the deflection of the columns of the back wall, reinforcement being provided accordingly. Observation during the winter following the completion of the straight portions of the structure indicated that the provision for expansion and contraction was adequate and that it behaved as anticipated.

Accessory Accommodations.—The seats consist of a 2 by 10 in. fir plank attached to a galvanized strap steel support by means of lag screws driven from beneath so as not to disturb the upper surface of the plank. The planks were painted a concrete gray with white lead paint to match the concrete. The seats project 4½ in. in front of the riser on which they rest in order that the spectator's feet may swing back under his seat and to allow rainwater to flow down the deck without wetting skirts of seated spectators. The spacing is 28 in. back to back of the planks. These seats have proved to be comfortable and entirely satisfactory and were decidedly cheaper than the more elaborate designs.

Offices, team rooms, locker rooms, and store rooms were provided under the terminal tower at each end of the U, from which an enclosed passageway leads directly to the field.

Ticket selling facilities are arranged so that the tickets are taken while passing turnstiles leading into the iron fence inclosure.

Provision was made for utilizing the space under the seat banks for sheltered track events, the first and third bays being entirely unobstructed. This space is also available as shelter from rain. Making this space available added considerably to the cost of the structure.

Owing to the absence of any information concerning the acoustics of a stadium, it was impossible to give this element any consideration. Owing to the fact that the rear seats are nearly a hundred feet farther from the cheer leader than the lowest row, approximately one-tenth second difference results in the issuance of the yells, which causes a slight blur. An overhanging balcony may aid in projecting a yell to the team or to opponents on the opposite side.

Rather ample toilet space was provided because observation at certain other stadiums revealed the urgent need of such provision.

Cost.—The contract price on grading, draining and sodding the field, and completing the track was nearly $100,000, hence the actual contract cost of the structure itself was approximately $12 per seat for the entire structure. It was about $14 per seat for the portion completed under the first contract.

Inasmuch as a fairly complete description has already been published,* not more has been attempted in the above discussion than a very brief description of the structure and a word of explanation concerning certain features of design. Nothing has been included above concerning the design of the field, the drainage and sewerage, as these were considerations somewhat apart from the stadium as a structure.

The stadium was designed under the direction of the writer as consulting engineer and was built by the Unit Construction Co., of St. Louis.

**Engineering News-Record*, Nov. 9, 1922.

Inundation Methods for Measurements of Sand in Making Concrete.

By G. A. Smith* and W. A. Slater.*

1. *Preliminary Statement.*—It is with the purpose of developing the principles of a proposed method of accurate field measurement of sand and of water for concrete that the investigation reported in this paper was undertaken. The method proposed is based upon the belief that one of the important causes of variability in the strength of concrete is the variation in the quantities of sand and water introduced into successive batches of concrete, even when care is exercised in the measurements. Sand when measured by volume in either a loose or a compacted condition may show great variation in volume for a given weight of sand, depending upon the quantity of moisture in the sand. In one case the volume of the sand when moist was found† to be 49.7 per cent greater than the volume of the same quantity of the same sand when dry. A concrete using that sand and designed to be mixed in the proportions of 1, 2 and 4 of dry materials would in reality be mixed in the proportions 1, 1⅓ and 4 if the sand were measured in a moist condition such as that reported in the paper referred to. Although the figures given indicate a richer mix when the sand is used in a moist condition no advantage in strength is derived therefrom unless the quantity of water used in the batch is reduced for the richer mix. On the contrary, the probability is that if the same quantity of water per batch is added for the moist sand as for the dry sand the increase in the ratio of the water to the cement (due to the moisture content of the sand) will result in a decrease in the strength of approximately 15 per cent. At the same time the cost of the cement for a cu. yd. of concrete will be increased by about 15 per cent, perhaps 65 cents per cu. yd. of concrete with cement at $3.00 per barrel.

The above illustration shows that with the usual methods of measurement the proportions obtained, the cost, and the strength, may depend considerably upon the amount of moisture in the sand, but the conditions assumed are extreme and the effect of varying moisture in the sand will generally be less than that indicated in the illustration used.

Preliminary tests by R. L. Bertin reported before the 1922 meeting

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† Young and Walcott, "The Volume Moisture Relation In Sand and a Method of Determining the Surface Area Based Thereon," Proceedings Am. Soc. for Test. Mat. Vol. XX p. 147 (1920).

of the American Society for Testing Materials* indicated that the quantities of sand and water contained in a vessel of a given size are very nearly the same for all degrees of moisture in the sand provided that the sand is placed by pouring it into water in the vessel instead of placing it in a vessel containing no water. This being true it suggests a simple method of overcoming the great variability in the proportioning of concrete introduced by the variations in the unit volume of sand when the water content is not constant. It was primarily to investigate this phenomenon and its applicability to the measurement of sand for the making of concrete that the tests here reported were undertaken.

The tests were carried out at the Bureau of Standards. A portion of the expense of the investigation was borne by the White Construction Co. of New York. The Bureau of Public Roads furnished the crushed limestone used. Acknowledgment is made to R. L. Bertin, Chief Engineer of the White Construction Co., to J. C. Pearson, of the Bureau of Standards, for advice in outlining the program and for assistance in interpreting the tests and to J. R. Dwyer of the Bureau of Standards, for carrying out and interpreting certain of the tests.

2. *Scope of Investigations.*—In order to make the determinations cover a range in the qualities of the sand and the coarse aggregate which is approximately comparable to the variations likely to be encountered in practice, sands were selected which were predominantly of quartz and of limestone, respectively; coarse aggregates of quartz gravel, crushed limestone and crushed trap rock were used. To give a variety in the gradings, the sands were regraded so as to give as nearly as was convenient the fineness moduli 2.1, 2.6, and 3.1 for the quartz sand and 2.6, 3.1, and 3.6 for the limestone sand. The fineness moduli actually obtained are given in Table I. Each of the coarse aggregates, (the quartz, the limestone and the trap rock,) was regraded so as to give fineness moduli of 6.0, 7.16, and 8.0 for use in the measurement of surface water.

In the sand measurement tests the sands were used (a) dry, (b) moistened with 5 per cent of water, and (c) flooded with water. Under each of these conditions the quantity of sand which could be placed in a 0.1-cu. ft. measure in water was determined by placing it successively by the methods described in section 7. The amount of water in the container with the sand was also determined for all these conditions.

In order to furnish a basis for comparison of the results with those obtained by the methods of measurement ordinarily used in the making of concrete the quantities of dry, moist, and wet sand respectively which could be placed in the container without water were determined also. Results of the sand measurement tests are given in Figs. 5 and 6.

In concrete work the coarse aggregate is frequently used in a wet condition and it is important to know how much water is carried into the concrete by the wetness of the coarse aggregate. Tests were, therefore, made to determine the amount of water which could be carried by the coarse aggregate both as surface water and as absorbed water.

*See Proc. A. S. T. M. 1922, Part II, p. 404.

It was desired also to make concretes in which the sand was measured in water to see if any gain in the uniformity in the quantity of sand and water resulted in a corresponding uniformity in the consistency and strength of the resulting concrete. For this purpose the essential thing seemed to be to fix upon a definite mix to be adhered to in making concrete when the sand to be used varied widely in water content.

Only one coarse aggregate was used for all concretes; this was a quartz gravel having a fineness modulus of 7.16. Combinations of this coarse aggregate with four fine aggregates were used. The fine aggregates were the quartz sand having fineness moduli of 2.09, 2.55 and 3.04 respectively and the limestone sand having a fineness modulus of 2.99. For each combination the sand was used successively in the dry, moist, and wet conditions and specimens were made with the sand shoveled, screened, and rodded respectively into the water. Another set was made with the sand rodded into place but without water having been placed previously in the container. In all, the program included 120 6 x 12-in. cylinder specimens for compressive strength. A few extras not on the program were made to answer questions of procedure which arose during the progress of making the specimens. Results of the concrete tests are given in Figs. 8, 9 and 10.

TABLE I.—AVERAGE SIEVE ANALYSES AND FINENESS MODULI OF THE SANDS USED

Sieve No.	Percentage Retained							
	Quartz Sand				Limestone Sand			
	Original	1	2	3	Original	4	5	6
4	2.33	1.13	2.03	3.70	1.33	0.43	0.83	1.73
8	12.63	6.67	13.73	22.60	16.33	8.33	15.03	23.50
16	12.30	6.20	12.80	19.23	23.73	13.77	24.73	36.83
32	15.77	16.30	13.97	11.70	20.12	25.00	20.37	15.40
50	28.83	36.33	29.03	21.13	23.49	32.37	23.57	13.47
100	19.23	22.67	19.20	14.37	11.89	16.03	12.13	7.00
Pan	8.90	10.70	9.23	7.27	3.12	4.07	3.33	2.07
Fineness Modulus	2.51	2.09	2.51	3.04	3.04	2.55	2.99	3.55

3. *Materials.*—The sands were from two sources and differed in their physical characteristics. That referred to as quartz was Potomac River sand passing a ¼-in. sieve. It had a specific gravity of 2.68 and a fineness modulus of 2.51. That referred to as limestone sand was obtained from the Rosoff Sand and Gravel Corporation, Mailboro, N. Y. This sand had a dull slaty appearance and gave a strong reaction with hydrochloric acid, but was not completely dissolved. The sand grains were irregular in shape and had the appearance of crushed stone modified slightly by churning in water. The limestone sand had a specific gravity of 2.69 and a fineness modulus of 3.04. The sieve analyses of the sands are given in Table I.

The coarse aggregates studied were quartz gravel, crushed trap rock and crushed limestone. The gravel was Potomac River gravel purchased locally. The trap was obtained from the New York Trap Rock Corporation. The crushed limestone was supplied by the Bureau of Public Roads, Department of Agriculture.

The cement used was purchased from a local dealer and met the standard specifications for portland cement.

Three sets of 2 x 4-in. mortar cylinders were made as control specimens for the cement. The results of the tests of these cylinders are given in Table II. In one set, batch 10, standard Ottawa sand and sufficient water to give normal consistency were used. The proportion of cement to sand was 1 to 3. In the second and third sets the sands used were the same as those used in the 6 x 12-in. concrete cylinders made in this investigation. In the second set, batches 2 to 5, the proportion of sand to cement and the proportion of water to cement were also the same as were used in the 6 x 12-in. concrete cylinders. In the third set, batches 6 to 9, a 1 to 3 mortar was used with the same percentage of water as for batch 10. The specimens remained in the moulds in a damp closet for 48 hours and then were stored in moist air (the same as with the concrete specimens) until the time of testing. The flow was determined on a small flow table using a truncated conical brass mold having a height of 2 in. and top and bottom diameters of 2¾ and 4 in. respectively. From batch 10 three specimens remain to be tested at the age of three months.

TABLE II.—TEST RESULTS FOR MORTAR CONTROL SPECIMENS.
(Each Strength is the Average for Three Specimens)

Batch No.	Proportions, parts by weight		Sand		Water, per cent by weight of		Flow, Percentage increase in diameter	Average Compressive strength (lb. per sq. in.)	
	Cement	Sand	Kind	Fineness Modulus	Cement	Cement and Sand		7 days	28 days
10**	1	3	Ottawa Sand	3.00*	40.8	10.2	21	2059	2778
2	0.54	1	Potomac	2.09	60.0	20.8	150	1730	2670
3	0.488	1	do.	2.51	60.0	19.7	154	1566	2826
4	0.434	1	do.	3.04	60.0	18.1	154	1600	2739
5	0.434	1	Limestone	2.99	60.0	18.1	153	1524	2815
6	1	3	Potomac	2.09	40.8	10.2	Dry	1809	2241
7	1	3	do.	2.51	40.8	10.2	Dry	2118	3307
8	1	3	do.	3.04	40.8	10.2	Dry	2769	4214
9	1	3	Limestone	2.99	40.8	10.2	Dry	3096	4586

* Fineness Modulus of Standard Ottawa sand based upon specified sizes and not upon sieve analysis.
** Strength at 3 mo. 4033 lb. per sq. in.

4. *Apparatus.*—In preparing the sands for test the dividing into small lots or samples was done by means of the Jones sampler shown in Fig. 1.

For the inundation tests the sands were measured in a cylindrical metal vessel having a height of 10.64 in., a diameter of 4.57 in. and a capacity of 0.1014 cu. ft. The top of the measure was ground to a plane

surface and fitted with a ground glass plate to prevent spilling while handling and cleaning the measure preparatory to weighing.

All weighing was done on a calibrated platform scale weighing correctly to 0.01 lb.

For placing the sand a small scoop, a ½-in. sieve, and a ¾-in. tamping rod, "bullet-shaped" at one end, were used. The ¾-in. rod was used also for striking off the excess material.

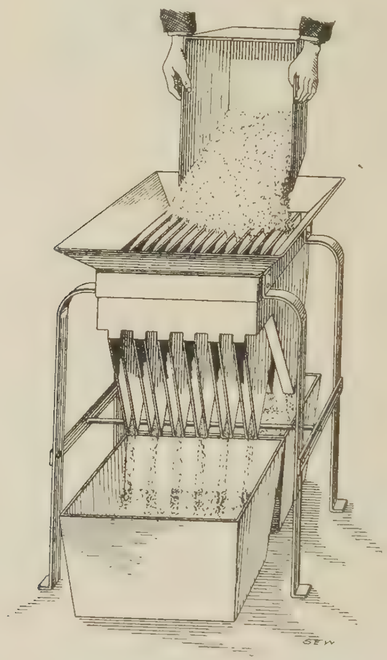


FIG. 1.—SKETCH SHOWING JONES SAND SAMPLER.

For measuring the coarse aggregate in the surface and absorbed water tests of aggregate, a cubical measure having a capacity of 1 cu. ft. was used. In order that the surface water carried by wet aggregate might be removed quickly a rotary screen lined with burlap was used.

In making the concretes, the mixing was done by hand in square pans with a blunt pointed trowel. The standard 4 x 8 x 12-in. truncated cone and the flow table were used in studying the consistency of the concrete. These apparatus are shown in Figs. 2, 3 and 4. The measure used in determining the weight per unit volume of concrete was cylindrical and approximately equal in height and diameter (6 x 6.1 in.) and had a volume of 0.0998 cu. ft.

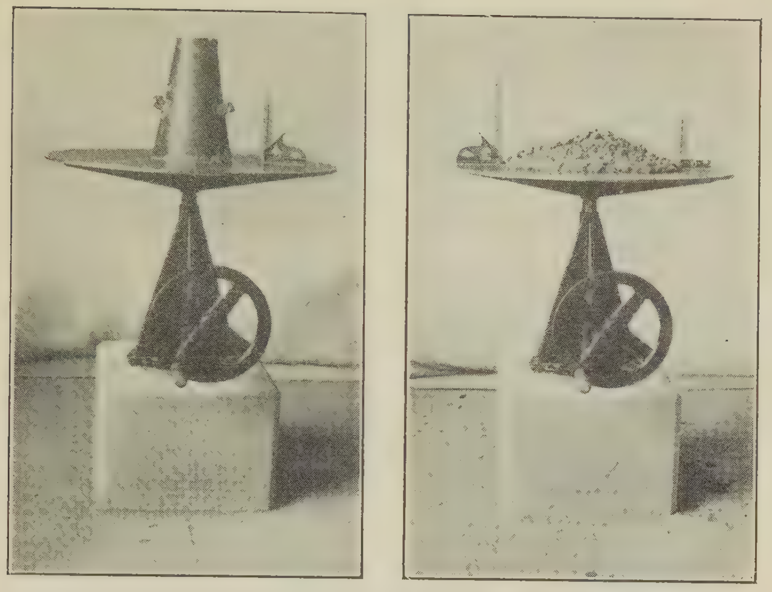


FIG. 2.—TRUNCATED CONE USED IN SLUMP TEST AND SPECIMEN AFTER REMOVAL OF CONE.

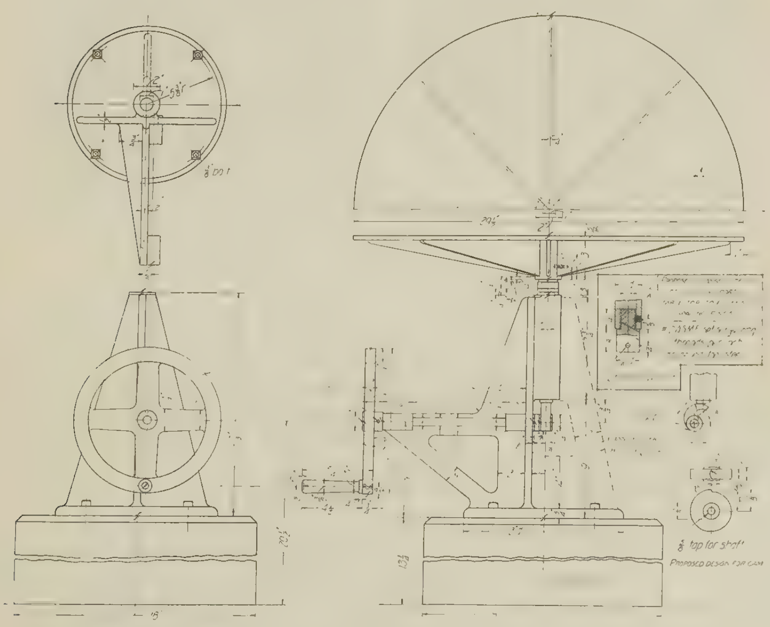


FIG. 3.—FLOW TABLE AS DESIGNED BY BUREAU OF PUBLIC ROADS WITH CHANGES PROPOSED BY BUREAU OF STANDARDS.

5. *Preparation of Materials for Sand Measurements.*—From preliminary determinations the amount of quartz and limestone sands necessary for all the tests was estimated. Each sand was then divided into parts which were sampled, analyzed and regraded to give the required fineness moduli.

The results of the sieve analyses of the original and the regraded sands are shown in Table I.

Sufficient sand for one test from each group of three companion tests was prepared at one time. To avoid segregation of the materials the Jones sampler was used for separating out the samples of dry sand. The

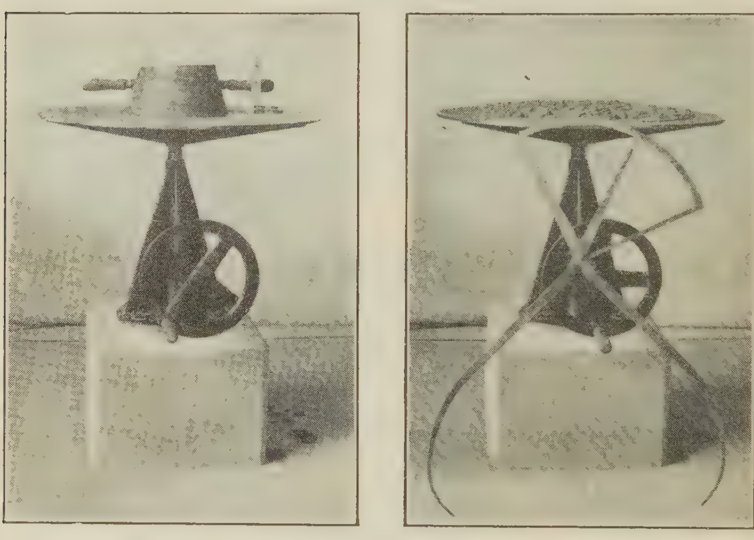


FIG. 4.—FLOW TABLE AND SPECIMEN AFTER DROPPING 30 TIMES THROUGH A HEIGHT OF 1/8 IN.

remainder of the sand was moistened with 5 per cent of water and the remaining individual samples were weighed out since with the moist sand there was little segregation. The samples to be used as moist sand were protected from loss of water by evaporation and those to be used as wet sand were flushed with water and kept until time for the test.

6. *Method of Testing.*—In measuring the sand four methods of placing the dry, moist, and wet sands were used:

(a) The sand was shoveled quickly with a small scoop into the measure without any attempt to break up the mass.

(b) The sand was broken up by screening it through a 1/2-in. sleeve.

(c) The sand was poured into the measure but at stages of 1/3 full, 2/3 full, and full, was rodded 25 times with a 3/4-in. rod having a "bullet-shaped" end.

(d) The sand was placed according to the A. S. T. M.* standard method of test for unit weight of aggregate for concrete, except that the height of the measure was 2.33 times its diameter. With this method the sand was placed in the measure in air and not in water, and was compacted by rodding as with method (c).

In measuring the sand in water (inundated) the measure was filled approximately half full of water and then filled with sand. After striking

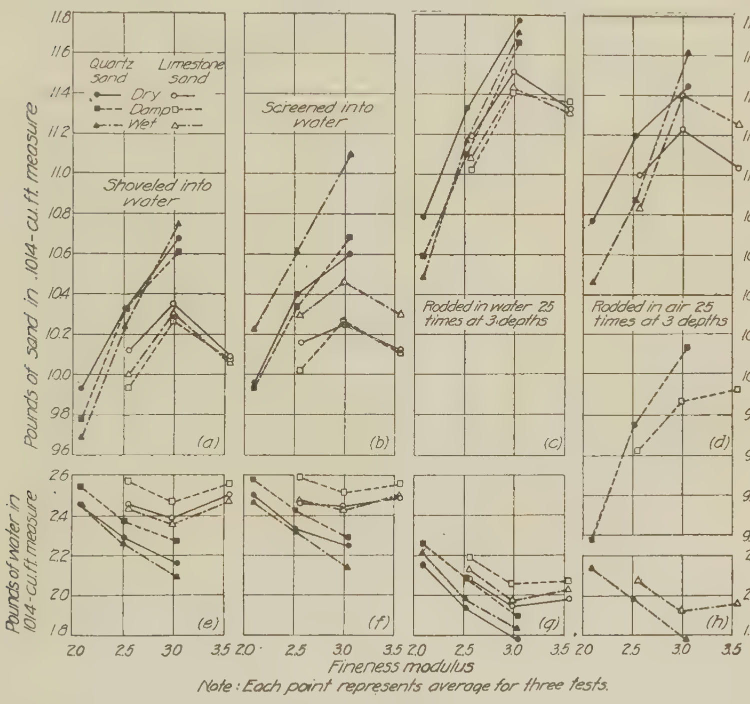


FIG. 5.—WEIGHTS OF SAND AND OF WATER FROM SAND MEASUREMENT TESTS.

off the surface the glass plate was placed on the top of the measure. The whole was then dipped in water to wash off the adhering sand, dried and weighed. Each measure of sand and water was dumped upon a large sheet of heavy wrapping paper and spread out to dry. When air dry the sand was again weighed and saved for use in making the concrete.

7. *Effect of Gradation on Compactness.*—In this investigation the fineness modulus has been used as a measure of the gradation. A low fineness modulus indicates a fine sand and a high modulus indicates a coarse sand. In Fig. 5 the weights of the sand, exclusive of moisture,

*A. S. T. M. Standard Specifications C 29-21.

have been shown as ordinates and the fineness moduli as abscissas. Each point represents the average for the three measurements of its group. That figure shows that in general with an increase in the fineness modulus the weight of the sand per unit volume increased until a fineness modulus of about 3 was reached. For all cases in which the limestone sand was inundated the weight per unit volume was less for a modulus of 3.5 than for a modulus of 3. With the dry and the wet sands measured in air (not inundated) the change in weight with change in fineness modulus was of the same nature as that described for the inundated sand. With the moist sand, however, measured in air the compactness was slightly greater when the fineness modulus was 3.5 than when it was 3.

8. *Effect of Moisture on Compactness.*—The data obtained by weighing known volumes of sand placed in a container without water are given in Fig. 5 (d) and those obtained with measurements of inundated sand in Fig. 5 (a), (b), (c), and (e). The volume occupied by a given weight of the finest sand used (quartz sand) exclusive of the weight of the water contained was 1.17 times the volume occupied by the same weight of sand when placed dry. For the coarsest sand used (limestone sand) the corresponding ratio of volumes was 1.11. With the sand shoveled into water the variation in unit volume with variation in moisture content of the sand was less than 2 per cent. It may be concluded that within practical limits the change in volume of sand was eliminated by the measurement of the sand in water. It will be seen in Fig. 5 (d) and (c), that the change in volume was eliminated also by using flushed sand placed in air. This may be accounted for by the fact that so much water was present that the sand was practically "inundated."

9. *Effect of Method of Placing.*—The purpose in using different methods of placing the sand in water was to discover which method would give most nearly the same quantity of sand in a measure, regardless of the condition of the sand, that is, whether dry, moist, or wet. Obviously the shoveling method would be easier of application in practice and it is of interest that this method gave also the most nearly uniform results. The securing of uniformity is probably the most important single consideration in the application of the results of this study to the making of concrete. It is not improbable that a combination of the screening and rodding methods would have yielded more nearly uniform results than the shoveling method, but it is unlikely that such manipulation would be economical.

The screening method resulted in the smallest percentage of air voids (see Fig. 6) and the rodding method gave the largest quantity of sand and the smallest quantity of water of all the methods used with inundated sand.

It will be seen in Fig. 5 (d) and (h) that the quantities of dry sand and wet sand when placed in the measure in air were not far different

from the quantities found when the sand was rodded in water. On the other hand the quantities of damp sand which could be placed in the measure in air were much smaller than the quantities of dry sand or wet sand when measured in the same way.

10. *Water Contained with Sand in Inundation Tests.*—The amounts of water contained with the sands are shown in Fig. 5 (e) to (h). As the sand showed increasing compactness with increasing fineness modulus (up to about 3.0 for the limestone sand) so the quantity of water contained showed a corresponding decrease as the modulus of the sand increased up to 3.0. The damp sands measured in water showed greater water content than either the dry or wet sands. It might be expected that any method

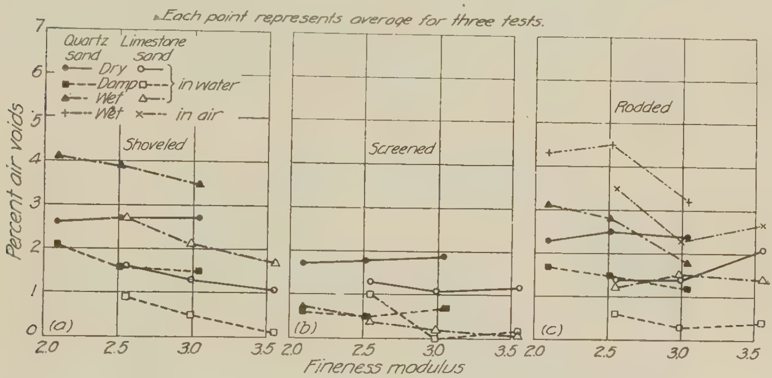


FIG. 6.—AIR VOIDS IN MIXTURE OF SAND AND WATER.
(Percentage of volume of measure.)

of placing which would result in an increased quantity of sand in the container would also result in a decreased quantity of water in the container. In general, this relation between quantity of sand and quantity of water was found to exist. The cases in which the sand was screened into water, however, form an exception. Although the measure held more sand when the sands were screened into the water than when they were shoveled in, the amount of water contained was also slightly greater. This may possibly be explained by the fact that the air voids were small for the screened sand.

11. *Weight of Sand from Combined Weights of Sand and Water.*—The fact that regardless of its moisture content a definite volume of sand when placed in water was found always to occupy the same volume, suggests the possibility of determining the amount of sand present from the combined weight of sand and water. By making use of the apparent specific gravity of the sand (instead of the true, in order to take account of

air voids) equation (1) gives the quantity of sand. This equation assumes that the weight of water is 62.4 lb. per cu. ft. for all temperatures considered.

$$W_s = \frac{W - 62.4\,V}{1 - \frac{1}{g_a}} \quad \text{where} \qquad (1)$$

V = volume in cu. ft. of the container used.

W_s = weight of sand, in pound in the container.

W = combined weight of sand and water in the container.

g_a = apparent specific gravity of the sand.

It was found that by using the apparent specific gravities determined from the inundation tests the quantity of sand used in the concrete specimens could be determined very closely by means of Eq. (1) and the combined weight of sand and water.

TABLE III.—GRADING OF SAMPLES FOR DETERMINATION OF SURFACE WATER AND ABSORBED WATER.

Fineness Modulus	Percentage of Aggregate			
	¼ to ⅜-in.	⅜ to ½-in.	½ to ¾-in.	¾ to 1-in.
6.0	100	0	0	0
7.16	17.8	15.6	33.3	33.3
8.0	0	0	0	100

Eq. (1) is the equation of a family of straight lines, and a diagram can be easily prepared which would be of considerable assistance in the determination of the quantity of sand in a measure of known volume.

12. *Surface Water and Absorbed Water in Coarse Aggregates.*—Samples of quartz pebbles, crushed limestone and crushed trap rock were graded so as to give fineness moduli of 6.0, 7.16, and 8.0. The proportions of the materials of different sizes were as given in Table III.

A sample 1 cu. ft. in size (measured according to A. S. T. M. standard C 29-21) was weighed when air dry and then flushed with water and allowed to soak for at least 20 hours. The sample was then spread out on a fine mesh screen, allowed to drain for three minutes and then weighed again. Most of the surface water was then removed by passing the sample through a rotating circular screen lined with burlap. The sample was then spread out, turned and mixed until the surface was dried to a uniformly dull appearance and was weighed again. The differences between the second weighing and the third weighing are shown in Fig. 7 as the

surface water for the quartz and the crushed trap rock aggregates. The differences between the first and third weighing are shown as the absorbed water for these two types of aggregate.

The results for the limestone tests could not be used for this report because the amount of loss by abrasion in carrying out the tests was so great as to vitiate the results. There was also some loss of trap rock by abrasion and the effect is seen in the form of an apparent negative quantity of absorbed water for certain cases. Apparently, however, the amount of water absorbed by the trap rock aggregate was not large

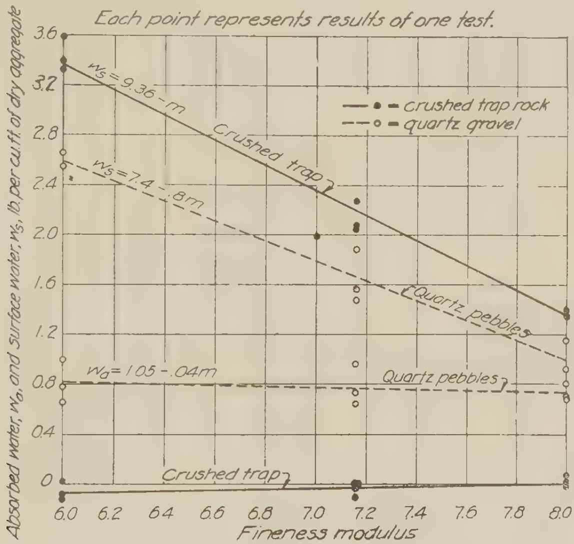


FIG. 7.—ABSORBED WATER AND SURFACE WATER IN COARSE AGGREGATE.

enough that it would be considered as affecting the amount of water in the batch of concrete.

13. *Proportioning of Materials for Concrete.*—The methods used in proportioning the materials were those described in Bulletin 1 of Lewis Institute "Design of Concrete Mixtures," by D. A. Abrams and in a paper "Field Tests to Determine Proportions for Concrete" by Stanton Walker, Proceedings A. C. I. 1922, p. 182. A strength of 2,000 lb. per sq. in. at 28 days (assuming the cement used to be similar to that used in the investigations reported in Bulletin 1), and a slump of 6 to 7 in. were made the basis of the design. Aggregate having a maximum size of 1 in. was used. With these conditions fixed the diagram Fig. 1, p. 184, of the latter paper indicates that one part cement to four parts of mixed aggregate having a fineness modulus of 5.4 is required. The three quartz sands

and one limestone sand used in the inundation tests were used as fine aggregate. The coarse aggregate had a fineness modulus of 7.16. The fine aggregates were mixed with the coarse aggregates in such proportions as to give the desired fineness modulus of 5.4 for the mixed aggregates for all concretes. The proportions given in Table IV were used for this purpose.

In order to make use of the water formula of Bulletin 1, "Design of Concrete Mixtures," in determining the amount of water the "relative consistency" of the concrete must be known. Bulletin 1, does not give the relative consistency which corresponds to a slump of 6 to 7 in. but by interpolating between the values given in that paper a relative consistency of 1.13 was obtained. Using this relative consistency in the water formula referred to it was found that a water-cement ratio of 0.78 by volume would be required. Upon trial it was found that this quantity of water gave a slump of only 0.3 in.* The amount of water necessary to give a

TABLE IV.—PROPORTIONS OF MATERIALS FOR CONCRETES, AND PROPERTIES OF AGGREGATES.

Sand No.	Fineness Modulus	Parts by Volume			Mixed Aggregate	
		Cement	Sand	Gravel	Fineness Modulus	Weight lb./ft.^{3}
1	2.09	1	1.64	3.17	5.40	124.5
2	2.55	1	1.76	2.99	5.38	125.2
3	3.04	1	1.95	2.76	5.38	125.0
5	2.99	1	1.95	2.76	5.38	124.8
				Av.	5.39	124.9

slump of about 6 in. was then determined by trial and it was found that this corresponded to a water-cement ratio of 0.6 by weight (0.9 by volume). The weight of the water in all the concretes was, therefore, maintained at 0.6 times the weight of the cement used.

The water contained in any batch of concrete came from four sources:

(a) Water in the sand.

(b) Surface water in the coarse aggregate.

(c) Absorbed water in the coarse aggregate.

(d) Water added to make up the amount required; here termed the "complement of water."

The amount of water in the sand for any concrete specimen using inundated sand, item (a), was assumed to be the same per unit volume of sand as the average obtained from the corresponding inundation test.

*The reason for the failure of the water formula to give the correct quantity of water may possibly be explained partly by the fact that the slump referred to in Bulletin 1, was based upon the use of a 6 x 12-in. cylinder specimen while a 4 x 8 x 12-in. truncated cone specimen was used in these tests. However, the difference in form of specimen is not sufficient to account for the small amount of slump found.

Since the surface water in the coarse aggregate may be considered as available for hydrating the cement, it was necessary to take this into account in determining the complement of water, item (d), to be added to make up the total of 0.6 times the weight of the cement. This was done by means of the equation in Fig. 7 for surface water for quartz pebbles.

The absorbed water was not considered available for hydrating the cement and, therefore, no deduction for item (c) was made in determining the complement of water. It is evident, then, that the total weight of the water present was equal to 0.6 times the weight of the cement used plus the weight of the absorbed water.

Since with the specimens made with dry aggregates [See Fig. 8 (e) and (j), Fig. 9 (d) and (h), and Fig. 10 (d)] no absorbed water was present, it is evident that those specimens contained a smaller total amount of water than did the specimens made with wet aggregate. The smaller slump and flow and the greater strength for the specimens made with dry aggregate is possibly an effect of the smaller quantity of water in these specimens, than in those made with wet aggregate. See Figs. 8 and 10.

The complement of water, item (d), was 0.6 times the weight of the cement less the sum of items (a) and (b).

14. *Preparation of materials for Concrete Specimens.*—A quantity of cement, sufficient to meet the requirements of the whole series of tests, was mixed on a large canvas and then stored in covered cans until used. The sands were prepared in the same manner as for the inundation tests of sand except that only the dry sands were separated into samples of the size required for individual specimens. The moist sands and wet sands were stored in large containers from which they were scooped as needed. The coarse aggregate was washed, dried, screened and recombined. Equal parts of ¼-in. to ½-in., ½-in. to ¾-in., and ¾-in. to 1-in. gravel were weighed out, dumped in a pile and mixed by shoveling. The quantities of cement and gravel required for individual cylinders were weighed out and stored in separate covered cans until the time of making the specimen. For all specimens in which inundated sand was used the gravel was covered with water immediately after weighing. For all other specimens the gravel was kept dry.

15. *Making and Storage of Compression Specimens.*—The quantities of materials used in each batch of concrete were sufficient to give enough concrete to fill a 6 x 12-in. cylinder mould. The flushed gravel was first drained over a ¼-in. sieve for three minutes, (thus conforming with the procedure followed in determining the surface water in coarse aggregate) and then dumped into the mixing pan. During the draining of the gravel the sand was measured in water (inundated), weighed to give the total weight of sand and water, and then dumped into the pan with the gravel. The water complement and the cement were then added and the ingredients mixed for two minutes. With this procedure the slump test was begun

(with only two exceptions) within approximately one-half minute of the time of completing the mixing of the concrete. The flow test followed the slump test immediately and the weighing of 0.1 cu. ft. of concrete followed the flow test. The cylinder moulds, which were set up on individual planed-steel plates to give true bottoms to the cylinders, were then filled. When the concrete had settled and become partially hardened the top surface was brushed and capped with neat cement. After about 48 hours the cylinders were stored in a damp-room, and sprinkled once daily.

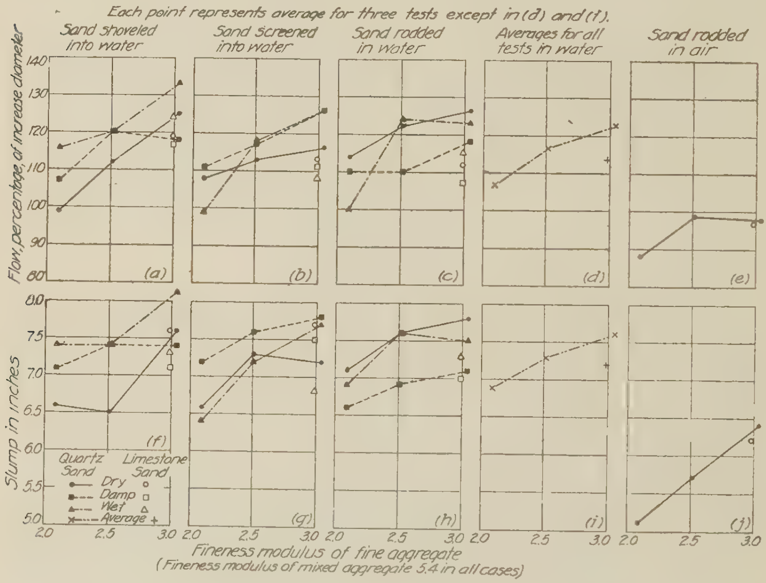


FIG. 8.—SLUMP AND FLOW FOR ALL CONCRETES.

16. *Slump and Flow Tests.*—The slump tests were made with the appartus shown in Fig. 2, in the manner described in the A. S. T. M. Proceedings, Vol. 20, (1920), p. 304. The average slumps for the groups of specimens (averages for three companion specimens) are shown in Fig. 8 (f) to (j). The flow tests were made with the flow table shown in Figs. 3 and 4. The table top and the specimen were dropped 30 times through a height of ⅛ in. The average percentages increase in the diameter for groups of specimens are shown as "flow" in Fig. 8, (a) to (e). The average variations from the average values for the slump and the flow were 5.3 and 5.4 per cent respectively. Fig. 8 indicates that for the measurements in water the condition of the sands or the method of placing had no noticeable effect on the slump or the flow. On the other hand although the fineness modulus of the mixed aggregate was 5.4 in all con-

cretes, both slump and flow showed increases as the fineness modulus of the fine aggregate increased. It should be noted that the very satisfactory equality of performance of the slump and the flow tests was probably due to the fact that all the mixes used were rich in cement.

17. *Weight Per Cubic Foot and Yield.*—For all the specimens the average weight of concrete was 145.3 lb. per cu. ft. and the average yield was 0.663 cu. yd. of concrete per barrel of cement. The average weights and the average yields for the different groups of three companion specimens each are shown in Fig. 9. The constancy of weight and constancy

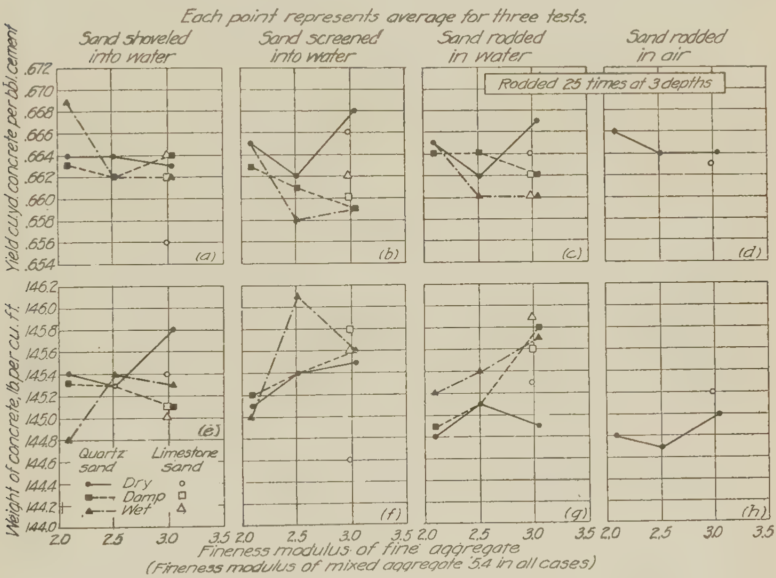


FIG. 9.—WEIGHT PER CUBIC FOOT AND YIELD OF CONCRETES.

of yield, which are evident in that figure, probably are due to the fact that the unit weight of mixed aggregate was nearly constant for all concretes and to the fact that the ratio of cement to aggregate was kept constant. Other factors would be expected to have little effect on the weight per cubic foot and yield when the water-cement ratio was kept constant. The maximum variation of any individual weight per cubic foot or of any individual yield from the averages for the entire investigation was approximately one per cent.

18. *Compressive Strength of Concrete.*—The strengths of the concretes are shown in Fig. 10. Each plotted point represents the average strength for the three companion specimens of its group. The average strength for all the concrete made with inundated quartz sand was 2130

lb. per sq. in. The highest and the lowest group averages shown are 7 per cent higher and 6.5 per cent lower than this average. The average strength for the concretes made with inundated limestone sand was 2350 lb. per sq. in. The highest and the lowest group averages were 5.6 per cent and 6.4 per cent above and below this average. The average strengths corresponding to the different fineness moduli lettered below the respective points indicate that the variation in strength with a variation in the fineness modulus of the fine aggregate was very small and that this variation was not systematic. The conclusion seems to be justified that with a given aggregate the quantities of materials obtained when the sand was measured in water were nearly enough constant regardless of the moisture content of the sand to give strength of concrete as nearly uniform as would be obtained by any other method of sand measurement.

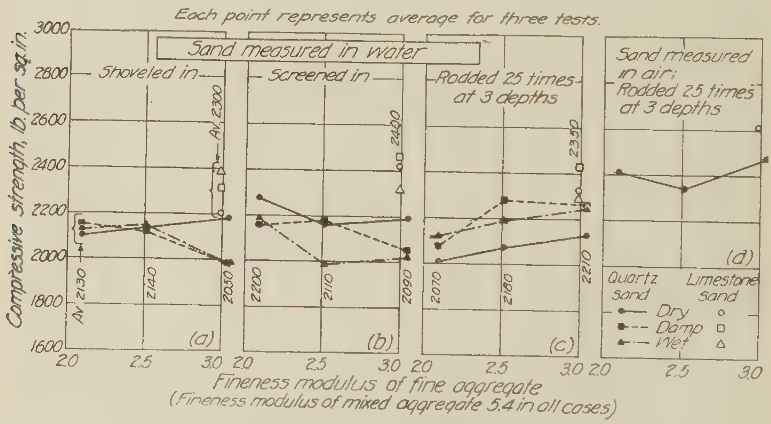


FIG. 10.—COMPRESSIVE STRENGTH OF CONCRETES.

In the concretes used, a variety of gradations of sand were employed in order to cover the range likely to be met in practice. Sands of two different characteristics also were used. The uniformity of strengths for the concretes using the same sand with different gradations indicates the applicability of inundation methods of measurement throughout this range and gives confidence in the fineness modulus as a device for proportioning concrete within the range covered by these tests.

In comparing the strengths reported in this paper with those reported in Bulletin 1, of Lewis Institute account must be taken of the fact that 2x4-in. standard sand 1: 3 mortar cylinders gave a strength at 28 days of 2778 lb. per sq. in. when made with cement used in this investigation and 3200 lb. per sq. in. with cement of the Lewis Institute investigation.

The strength of the concrete made with limestone sand averaged approximately 10 per cent greater than that of the concrete made with the

quartz sand of the same fineness modulus. Correspondingly the slump and the flow were less for the limestone sand concrete than for the quartz sand concrete. This is shown in Fig. 8. The increase in strength is apparently consistent with the decrease in flow but the reason for the difference of strength and flow from those of the quartz sand concrete does not seem to be explainable on the basis of data obtained in these tests.

The strengths of the concretes in which dry aggregates were used is in all cases greater than the strengths of corresponding concretes in which the sand was measured in water and in which the coarse aggregate had been previously wetted. See Fig. 10 (d). Correspondingly, the slumps and flows for the former concretes were less than the slumps and flows for the latter concretes. See Fig. 8 (e) and (j). More water was added to the batches using the dry aggregate than to those using wet aggregate to make up for the surface water carried in by the wet coarse aggregate. Apparently a similar addition should have been made to correct for the absorbed water carried in by the wet aggregate. This, however, was not done and may account for the smaller slump, smaller flow and the higher strengths of the concretes made with dry aggregates.

19. *Summary.*—In considering the applicability of inundation methods of measuring sand, to the making of concrete it should be remembered that such accidental variations in the gradation of the sand as may occur in the field were eliminated in these tests. Other features of the laboratory tests also may not be duplicated in the field. It does not seem likely that such accidental variations need be important but only field application of the method can determine as to its practicability. The following paragraphs summarize the results of the investigation.

(1) The results of the tests indicate that when sand is measured in water the quantity of sand per unit of volume is almost constant regardless of the original water content of the sand and that the water filling the voids in the sand is also nearly constant for any given method of placing the sand.

(2) The shoveling of the sand into the water gave more nearly constant quantities of sand and of water per unit of volume than any of the other methods used.

(3) The screening method gave slightly larger quantities of sand and slightly smaller quantities of water per unit volume than did the shoveling method and the results of the tests indicate a lower percentage of air voids for this method of placing the sand than for either the shoveling or the rodding methods.

(4) The rodding of the sand in water gave a larger quantity of sand per unit of volume than any of the other methods used.

(5) Placing the dry sand and the wet sand according to the A. S. T. M. standard C29-21 gave quantities of sand per unit of volume slightly

less than when the sand was rodded after shoveling it into the water. The quantity of sand obtained when moist sand was rodded in air was much less than when it was rodded in water.

(6) The inundation method of measurement when used with a predetermined apparent specific gravity may afford a convenient means of determining the proportion of sand to other concrete materials even for jobs on which the materials are being measured by other than the inundation method.

(7) The variation in surface water per cu. ft. of coarse aggregate was approximately proportional to the variation in the fineness modulus of the coarse aggregate. The quantity of surface water was considerably greater for the crushed trap rock than for the quartz pebbles. The quantity of surface water averaged about 9 per cent of the total water used in the concretes of these tests or about 8 per cent by volume of the cement. The quantity of absorbed water per cu. ft. was greater for the quartz pebbles than for the crushed trap and was independent of the fineness modulus.

(8) For concretes made with quartz sand measured in water the strengths were nearly the same regardless of the condition of the sand, the method of placing it, and the proportion of fine aggregate to coarse aggregate.

The indication is that the measurement of sand by inundation methods should be of assistance in reducing variability of strength of concrete caused by variations in quantities of sand and water in a batch.

The use of a constant water cement ratio for the concrete together with a constant fineness modulus for the mixed aggregate resulted in nearly a constant strength regardless of the proportion of fine to coarse aggregate in the mix.

(9) The use of a constant fineness modulus of the mixed aggregate did not result in a constant slump or flow for the concrete. The variation in each was approximately proportional to the variation in the fineness modulus of the fine aggregate in the mix.

(10) The weight of the concrete per cu. ft. and the volume yield of concrete per barrel of cement were practically constant.

DISCUSSION.

R. L. Bertin.—The fund of knowledge which in the past few years has been added to the concrete art through the tireless efforts of investigators, has reduced the design of reinforced-concrete structures to an almost exact science, and brought to light the principles underlying the making of concrete. Mr. Bertin.

Concrete as produced today is not sufficiently uniform to warrant a material reduction in the safety factors, and not until the concrete manufacturers have modified the present methods of selecting the concrete materials, proportioning them, and measuring them as well as the methods of conveying, depositing and curing concrete with a view of better control, will better, cheaper and more uniform concrete result and permit a reduction of safety factor.

Uniformity of proportions is particularly inmportant; the present method of loose volumetric measurement is most unsatisfactory and responsible to a large extent for the erratic results in strength which have been obtained. The unreliability of volumetric measurement is chiefly due to the inherent properties of the fine aggregate to hold varying amounts of water and bulk, in some cases as much as 40 percent, under certain conditions of moisture content, these variations affect materially the absolute amount of sand and water introduced in batches, and consequently the resulting concrete.

In order to show conclusively the necessity of accurately measuring the concrete ingredients, I propose to demonstrate by test, the effect which the sand variations just mentioned have on the yield, and cost of concrete. I shall first determine the absolute amount of sand and water contained in a given volume filled loosely with a sand in three different conditions: first, dry; second, containing 2 percent of water, and third, containing 6 percent of water by weight.

Table I gives the results of the tests corrected to lb. per cu. ft., and shows the weight of sand and water contained in a cubic foot, the percentage of bulking, and the volume of dry sand, which when moist, fills one cubic foot for the three conditions above mentioned.

With a view of compensating for the variations just demonstrated, a method of measuring sand in an inundated condition was devised, based on the principle that if the voids in the sand are completely filled with water, the variations in original water content will be eliminated, and the bulking tendency done away with, thereby making it possible to measure sand volumetrically and obtain fairly uniform results irrespective of the condition of the sand.

I shall next show the weight of sand and water contained in a given volume filled with inundated sand, using the sand in two of the conditions used in the previous test, namely, dry, and containing 6% of moisture.

Table II gives the same values as Table I for sand measured by the inundation method.

Mr. Bertin.

TABLE I

Method of Measuring Sand	Sand Conditions — Per Cent of Water by Weight	Weight of Sand (dry)	Weight of Water held by Sand	Per Cent of Bulking	Volume of Sand when dried, cu. ft.
Ordinary volumetric method	0	105	0	0	1.00
	2	95	2.16	19	0.81
	6	83	4.95	26.1	0.739

TABLE II

Inundation method	0	105.5	21.6	0	1.00
	6	104	22.0	1.01	0.9899

It is to be noted that the weight of dry sand in a cubic foot when measured by the inundation method is almost the same whether the measured sand is dry or damp, and very nearly the same as the weight of dry sand loosely measured in a dry condition; also that the weight of water contained in a cubic foot of inundated sand is practically the same whether the measured sand is dry or damp.

Two batches of concrete were mixed in the proportion of 1: 2.2: 4.2, using sand containing 6 percent of moisture; for the first batch, the sand was measured in the manner described in the first sand test, and for the second batch, the sand was measured inundated—the only difference between the two batches being, the weight of sand used, the variation being due to the sand bulking. The results of the test are tabulated below.

TABLE III

Batch No.	Methods of Measuring Sand	Material Factors: Cement, bbl.	Sand, yd.	Stone, yd.
1	Ordinary volumetric method	1.51	0.389	0.935
2	Inundated method	1.40	0.456	0.87
	Difference	0.11	−0.067	+0.065

It is to be noted that by the use of the inundation method of sand measuring, less cement, more sand, and less stone were required per yard of concrete, the difference in cost favoring the second batch. The concrete proportions used in the cement test were determined by the use of a method which suggested itself to Mr. Slater and myself during the course of our work on the inundation method of sand measuring. Briefly, the method is as follows.

First, determine the densest combination of the available sand and stone which can be made. This is accomplished by taking a fixed volume of the fine aggregate and adding to it little at a time, known volumes of

coarse aggregate, for every addition of coarse aggregate, determine the weight of the mixture per cubic foot, when the maximum weight has been reached, determine the percentage of sand and stone in the mixture; this is the limit beyond which no more coarse aggregate can be added and a workable mix be obtained. The mixture is, 1st, the mixture having the highest permissible percent of coarse aggregate, and the least of fine aggregate, therefore the highest permissible Fineness Modulus; 2nd, the mixture having the minimum percent of voids, and 3rd, the mixture having the least permissible surface area.

Second, prepare a cement paste having a water-cement ratio by volume such as will satisfy the following equation for the strength desired:

$$S = \frac{14000}{9x}$$

where S equals compressive strength per square inch at 28 days, and x equals the water-cement ratio by volume.

Third, gradually add the cement paste thus prepared to a mixture of the fine and coarse aggregates, mixed in the proportion determined by the method above described, until concrete of the desired consistency results, when this condition obtains, determine the amount of cement paste used, and therefrom derive the proportion of water-cement-sand-and-stone volumetrically or otherwise. The proportions thus established will produce the most economical concrete for the materials at hand, capable of developing the required strength, and of the desired consistency.

For all ratios of cement paste to aggregate, the fineness modulus, the surface area, and the water-cement ratio remain constant, the cement-space ratio after a sufficient amount of the paste has been added to the aggregate to just fill the voids, also remains constant; the plasticity of the concrete can therefore be varied at will without affecting the strength of the concrete.

The determination of the densest mixture of sand and stone is advocated from the standpoint of economy, but is not essential for the determination of the ratio of cement to aggregate, which will produce a concrete of given strength for a given consistency. A poorly graded aggregate or a well graded one deficient in large particles will require more paste to obtain the proper consistency than a mixture of fine and coarse aggregate in which the coarse aggregate is as large as the nature of the work will permit, and the percentage of coarse aggregate such as to produce the densest mixture. This method is a simple way of comparing aggregates and determine their relative costs, based not only on their unit price but also on their concrete making properties.

The advantage of this method is that it takes care of all the factors which have been established as affecting the resulting concrete without the necessity of determining them. The equipment necessary is very simple and cheap, and the knowledge of all the intricate theories of con-

Mr. Bertin. crete making unnecessary. It also seems to satisfy the basic principles used by various investigators equally well, which if so, shows the close agreement of the different theories advanced.

Several of the phases of this method have already been used, for instance, the Navy has issued a new specification for concrete in which it describes the sand and stone measurement method given above.

The constant water-cement ratio is described by R. B. Young in his paper "New Methods of Proportioning Concrete," in which he states that when water is added sufficient cement shall be added to the mix to maintain the water-cement ratio constant.

This method therefore has no novel features except in the grouping in a complete method the known basic principles in such a way that the consistency is made a function of the ratio of cement to aggregate, all other variables affecting the strength remaining constant.

Mr. Johnson. NATHAN C. JOHNSON.—Any investigation of or proposed means for proportioning concrete which will direct attention to the necessity for accuracy in this step of manufacture, as contrasted with the present inaccurate ways in common acceptance, is a distinct benefit to the art.

The method of measurement of sand by "inundation," or saturation, is familiar to the writer from his own work along similar lines in 1911 to 1914. These investigations resulted in the development and patenting of a field testing instrument for sands wherein measurement of the different grades was accomplished by inundation or saturation of the sand so that volumes read as percentages. It was also endeavored at that time to apply the same method to the batch measurement of sands, but trials were so sloppy and cumbersome that it was then adjudged inexpedient to continue efforts along that line, as it was believed that these faults would cause its abandonment, open or concealed, by the workmen on a job on which it might be placed. It was also found that there were inherent and apparently ineradicable errors in the method, possibly due to impounded air, or possibly due to varying surface tensions in different sands.

These early efforts, however, resulted in a conviction that much of the present uncertainty as to the results which will be obtained in any concrete can be traced directly to inaccuracies and variations in proportioning. Volumetric proportioning as practiced in the field seems to be incurably inaccurate. The outgrowth of these studies was a method of and devices for weight proportioning, used first in Canada, and, for the past 2½ years, in the construction of the Sherman Island Dam at Glens Falls, New York, for the International Paper Co. In both of these constructions, the results have been eminently satisfactory and economical, with the compressive strength showing within 200 pounds of each other day after day and conforming fairly to predicted strengths from various formulae.

The method is theoretically correct as well as practically satisfactory. The variation of moisture in commercial sands rarely exceeds 3 percent

Mr. Johnson.

from one extreme to the other. Assuming 1500 lb. of sand per yard, this 3 percent variation is a total of 45 lb. as an extreme. As contrasted with the usual variation of from 600 to 800 lb. of sand in the same size batch when measured by volumetric methods, the percentage of improvement and of uniformity is easy of computation and is also borne out by weight of evidence in practice.

Weight measurement has the further advantage in that the stone can be measured with equal accuracy, and that cement can be used either in bulk or in split bag batches, making again for definite yield and for conservation of expensive ingredients.

Mr. Walker.

STANTON WALKER.—I have been very much interested in the method of measuring the volume of moist sand outlined in Messrs. Smith and Slater's paper and first described by Mr. Bertin before the 1922 convention of the American Society for Testing Materials.

Prompted by Mr. Bertin's paper, a few tests were carried out at the Structural Materials Research Laboratory, Lewis Institute, Chicago, to determine the variation in volume of sands containing different quantities of moisture when measured in an inundated condition.

Three different sizes of sand, fine, medium and coarse, were used. The sand was of limestone origin, from the pit of the Chicago Gravel Co., at Elgin Ill. The moisture content varied from a room-dry condition to 15% of water. The weight of dry sand contained in a cubic foot of moist sand was determined by means of a ½ cu. ft. cylindrical metal measure having height equal to diameter, by each of the following methods:

(1) Measure about ½ full of water (sufficient to inundate sand):
  (a) Sand poured into measure in steady stream,
  (b) Sand shoveled into measure with small hand scoop.

(2) No water in measure.
  (a) Sand poured into measure in steady stream.
  (b) Sand shoveled into measure with small hand scoop.

The weight per cubic foot of the dry sand was also determined by puddling into the measure with a pointed round rod, in accordance with the standard method of the American Society for Testing Materials.

The sieve analyses of the sands used are given in Table I. The fine sand was graded 0 to No. 30, the medium 0 to No. 8 and the coarse 0 to No. 4 sieve.

The sands were moistened by adding different quantities of water to 75-lb. batches of room-dried sand and thoroughly mixed on a metal board with shovels. The room-dried sand contained about 0.3% moisture for which no correction was made.

The weights of dry sand per cubic foot of moist sand as determined by the different methods of measurement are given in Table II.

The following conclusions may be drawn from these data:

(1) Quantities of moisture up to 15% had practically no effect on

Mr. Walker.

TABLE I.—SIEVE ANALYSIS OF SANDS

Tests made in accordance with "Tentative Method of Making Sieve Analyses of Aggregate for Concrete' of the American Society for Testing Materials. (C 20 – 21.)
Each value is the average of two tests.

Sieve No.	Size of Square Opening, inches	Amount Coarser than Each Sieve, per cent by weight		
		Fine	Medium	Coarse
100	0.0058	96	98	98
50	0.0116	66	83	84
30	0.0232	1	48	52
16	0.046	0	28	36
8	0.093	..	0	15
4	0.185	..	..	1
3/8	0.37	..	..	0
Fineness modulus*	....	1.63	2.57	2.86

* Sum of per cents in sieve analyses divided by 100.

TABLE II.—EFFECT OF MOISTURE ON THE VOLUME OF SAND

Weight of dry sand contained in one cubic foot of moist sand; measured in ½ cu. ft cylindrical measure having height equal to diameter.
In general each value is the average of two tests.

Moisture, per cent, by Weight of Dry Sand	Weight of Dry Sand, lb. per cu. ft. of Moist Sand					
	No Water in Measure			Measure Half Full of Water		
	Fine	Medium	Coarse	Fine	Medium	Coarse
SAND POURED INTO MEASURE IN STEADY STREAM						
0	94	102	107	97	..	109
1	84	91	96	94	..	109
3	75	81	89	95	..	108
5	71	79	86	96	..	111
7	69	77	86	95	..	109
10	68	78	87	95	..	111
15	71	79	95	93	..	110
Average	76	84	92	95	..	110
Mean variation, per cent	..	..	..	0.9	..	0.9
SAND SHOVELED INTO MEASURE WITH HAND SCOOP						
0	95	103	110	97	103	109
1	86	97	103	99	104	110
3	78	91	96	97	101	110
5	77	89	95	97	102	111
7	77	91	96	97	104	109
10	80	89	96	96	104	111
15	77	90	98	96	104	109
Average	81	93	99	97	103	110
Mean variation, per cent	..	..	..	0.6	1.0	0.6
SAND PUDDLED INTO MEASURE WITH ACCORDANCE WITH A.S.T.M. STANDARDS						
0	101	108	116	..	..	..

the volume of sand when measured in an inundated condition. For the inundation tests the average weight of dry sand per cu. ft. of moist sand and the mean variation from the average for all percentages of moisture used were as follows: Mr. Walker.

Size of Sand	Weight of Dry Sand, lb. per cu. ft. of Moist Sand		Mean Variation from Average, per cent	
	Poured into Measure	Shoveled into Measure	Poured into Measure	Shoveled into Measure
Fine O–No. 30	95	97	0.9	0.6
Medium O–No. 8		103		1.0
Coarse O–No. 4	110	110	0.9	0.6

(2) For sands measured in an empty vessel greater bulking was found for the fines ones than for the coarser. The maximum bulking in volume due to moisture obtained in these tests was as follows:

Size of Sand	Maximum Bulking Due to Moisture, per cent	
	Poured into Measure	Shoveled into Measure
Fine O–No. 30	38	24
Medium O–No. 8	33	15
Coarse O–No. 4	25	15

(3) The weight of sand measured in an inundated condition using the methods outlined above was about 4 to 5% less than when measured dry in accordance with the standard method of the American Society for Testing Materials.

In Messrs. Smith and Slater's paper it is pointed out that the materials for their concrete were proportioned in accordance with methods outlined in Bulletin 1 of the Structural Materials Research Laboratory, "Design of Concrete Mixtures," by D. A. Abrams, and in a paper by the writer on "Field Tests to Determine Proportions for Concrete" in the Proc. Am. Concrete Inst., 1922, p. 182.

It should be pointed out that the water-ratio-strength relation in the last-mentioned paper is somewhat different than that used in Bulletin E. The relation between strength and quantity of mixing water for the tests on which Bulletin 1 was based was found to be $S = \dfrac{14000}{7^x}$

where S = compressive strength at 28 days—lb. per sq. in.
x = water-ratio to volume of cement (an exponent).

Mr. Walker. The diagram in the American Concrete Institute paper was based on the following equation obtained by averaging the results of tests made over a period of about 8 years:

$$S = \frac{14000}{9x}$$

The latter formula requires a somewhat richer mixture for a given strength than the former.

Messrs. Smith and Slater assume that a 6 to 7-in. slump represents a relative consistency of 1.13. This appears to be incorrect. Our tests show that a relative consistency of 1.25 will give a slump of about 6 to 7-in. using a 4 by 8 by 12-in. truncated cone, and of 1.13 a slump of about 3 to 4 in. This error arises because of the differences in values of slump obtained by the use of the 6 by 12-in. cylinder and the truncated cone. Our tests have shown these differences to be approximately as follows for the commonly used concrete mixtures:

Relative Consistency	Slump	
	4 by 8 by 12-in. Truncated Cone	6 by 12-in. Cylinder
1.00	¼ to ¾ in.	½ to 1 in.
1.10	3 to 4 in.	5 to 6 in.
1.25	6 to 7 in.	8 to 9 in.

Their failure to obtain the expected slump by using the quantity of mixing water calculated from Eq. 1 in Bulletin 1 is accounted for in part by the above differences and in part by their apparent failure to take into account properly the quantity of water absorbed by the aggregate.

QUESTION BOX.

One session of the 1923 convention was devoted to a "Question Box." A number of questions of interest to concrete users were prepared in advance and certain members assigned to answer them. In the following the first discussion is, as a rule, the one assigned to the question, after which the discussion was open to the floor.

(A)—How may cinders be used for roof fill most successfully to avoid expansion and displacement of parapet walls?

L. C. WASON.—Briefly, my answer is, "Never use them." It is not necessary to get a pitch on the roof for drainage purposes. A flat roof is all right. I never heard of a case where cinders caused damage to a parapet wall but they do cause some damage to the roofing material. Around the downspouts, where the cinders are thinnest the roofing is sometimes broken and where the filling is thick and the roofing bends it is sometimes bulged upwards so as to break, due in part to the intense heat of the sun being absorbed by the cinders, causing expansion of a gas or air below the roofing. It has to be covered with 1 1/2 or 2 in. of mortar, as a minimum, to give a base on which the roofing can be mopped down. This, with the filling below it, adds to the cist of the roof. **Mr. Wason.**

So long a time elapses from the placing of cinders to the waterproofing that rains occur and the cinders are full of water when the waterproofing is put on. This not only comes in through the ceiling but sometimes drips for a year.

If insulation is necessary in the top story it can be more cheaply got by omitting all cinders and putting on one inch of cork, over which the waterproofing is placed.

A. C. SCHWELLER, JR.—I should like to ask if in the pitched roof it is considered advisable to use cinder concrete of a rather porous texture? Would this do away with the disadvantage he has in mind? **Mr. Schweller.**

H. D. LORING.—I think there is no question but what cinder concrete would give satisfactory results, but it would be about double the cost of dry cinders. I also doubt if the insulating power of cinder concrete would be quite as great as that of dry cinders if you can get them. Mr. Wason has pointed out that cinders are often saturated, but that would in time leak out. **Mr. Loring.**

JOHN A. FERGUSON.—A matter that came to my attention might be of interest in connection with cinder roofs. The owner of a building called me in about two years ago with the statement that the parapet wall was being shoved off the building to such an extent as to become dangerous. On investigation I found that the man who put this roof in had tried to do a bang-up job, and he had sure done it. He had a mixture of about 1:3 cinder concrete, and without expansion joints in the concrete nor in the contact between the concrete and the brick parapet walls. The expan- **Mr. Ferguson.**

sion was sufficient to be about double what would be calculated as the proper expansion for the change of temperature between the time of the putting in of the concrete and the time at which this trouble was discovered. However, the concrete was put in at a dry time and had become saturated with water in the meantime. That accounted for the double expansion; because concrete does expand very materially when it is wet. I should think it would be a fairly good suggestion for any one intending to put in a cinder concrete roof to leave most of the cement out and place it in the covering for the stiffness of the exact covering of the cinder fill, and then leave a plastic joint between the covering and the parapet wall. Our cure for the situation was simply to take out all contact between the cinder concrete roof covering and the parapet wall, etc., which were being shoved, and fill it with a plastic compound of asphalt.

(B)—Does the saving which the use of slag entails warrant its use in reinforced-concrete buildings?

Mr. Ferguson. J. A. FERGUSON.—I do not know of any saving which slag concrete would cause, except by the possibility of the use of higher working stresses, if you have the proper kind of crushed slag which has been properly weathered. Some investigations in which I myself had considerable interest showed that the crushed slag concrete aggregate did have very materially greater strength than concrete made with Pittsburgh gravel aggregate. I hesitate somewhat to mention the percentage of increased strength, as it came to my notice, because there might be some who think the percentage of increased strength is rather high, but it exceeded by 50% the strength of the gravel concrete. In other words, 2000-lb. gravel concrete could be balanced against 3000 to 3400 lb. concrete made with the crushed blast furnace slag. If the unit stresses were permitted by building regulations to be increased, as is done in Pittsburgh, in proportion to the increased strength of the concrete manufactured on the job, there might be a saving in proportion, but a person could not give a broad answer to the question; the saving would have to be worked out for each individual case.

Mr. Bertin. R. L. BERTIN.—I would like to ask Mr. Ferguson whether the cement was practically the same in both cases.

Mr. Ferguson. MR. FERGUSON.—The cement was the same in both cases, though the slag concrete ordinarily requires slightly more water; the cement ratio was the same in both cases.

(C)—Which of the following characteristics is most important in the making of good concrete; strength, density or impermeability? Give simple rules for obtaining the desired results.

Mr. Gonnerman. H. F. GONNERMAN.—This question is subject to two interpretations. One of these is, which of the three mentioned characteristics is the best

criterion of the quality of concrete in general, and the other is, which of these characteristics is it most important that a concrete should possess? Is it more important that a concrete should be dense or impermeable than that it should have high strength? The discussion to follow will be based for the most part on the first interpretation of the question.

Strength is the measure of the ability of concrete to resist the loads to which it may be subjected. *Density* is defined in various ways. As applied to concrete mixtures it is most commonly defined as the sum of the absolute volumes of the solids, that is, the cement and aggregate in a given volume of concrete. It is based on the specific gravities of the cement and aggregate, the weights of the materials used in the mix, and the "yield" of the concrete. *Impermeability* is the measure of the resistance which a concrete offers to the passage of water. It is frequently assumed that the absorption of concrete is a measure of its impermeability. Tests show that this is not the case. The absorption of concrete gives an indication of the amount of the air voids or pore space in the concrete to which water has access. These pores or voids are not necessarily connected and continuous and therefore may not permit the passage of water. On the other hand, in a concrete which is not impermeable these pores are more or less continuous, thus permitting water to penetrate and pass through the mass. Materials having the same percentage of absorption may vary widely in impermeability. While it has been pointed out that there is no direct relation between absorption and impermeability, it is true in general that these two characteristics of concrete are affected by the same factors.

Density is a desirable characteristic, but considered alone it does not indicate whether or not a concrete is of high quality. A dense concrete may be relatively weak so far as strength is concerned. On the other hand, data obtained at the Structural Materials Research Laboratory and in other laboratories, show that compressive strength gives a reliable indication of quality, high quality being accompanied by high strength and vice versa. There are fairly well-defined relations between compressive strength and other properties of concrete, such as wear, flexural strength, shearing strength, absorption, etc. If the strength of concrete is known other important properties of the concrete may be judged with a fair degree of accuracy. Strength, therefore, furnishes a direct and useful means of judging the quality of concrete which is not readily afforded by density or by impermeability. If a concrete made with given materials has high strength it may generally be assumed that the concrete is also relatively dense and impermeable, since the factors and conditions which affect the strength of concrete also affect in similar ways its density and impermeability.

There is no direct relation between density and strength for wide ranges in proportions, water content of the mix and grading of aggregate. Tests shows that concretes having the same strength may vary in density from about .54 to .84 and that concretes having the same density may

vary in strength from about 500 pounds per square inch to 6500 pounds per square inch. When, however, certain of the variables which affect the properties of concrete are properly controlled, a well-defined relation will be found to exist between density and strength. For example, if the grading and mix are kept constant and the amount of mixing water varied, a direct relation will be found to exist between density and strength.

Although there is no direct relation between density and strength, when the variables affecting the properties of concrete are not controlled, a general relation is found between density and strength when the amount of cement is considered in relation to the complement of the density, that is, to the air and water voids. There is also a very well defined general relation between the strength of concrete and water-cement ratio, the ratio of the volume of the mixing water used to the cement in the batch. When judging of the relative strengths of concretes the water-cement ratio is a more readily usable function than is voids-cement ratio, since it may be determined as soon as the concrete is mixed without having to make specific gravity tests and weighings of the materials used or determinations of the "yield" of the resulting concrete.

When concrete is used in construction reservoirs and conduits, and in structures exposed to the action of sea water, alkali soils and to the action of the weather, impermeability as well as strength becomes important and must be given careful consideration. Due to the difficulty and expense of making permeability tests of concrete, there are not as many data available on this question as there are on the other properties of concrete. Such data as are available, however, indicate that the factors which will produce concrete of high strength, will also produce impermeable concrete.

The slides which I shall now show give the relations which exist between density, voids-cement ratio, water-cement, ratio and compressive strength of concrete.

The first slide (Fig. 1) shows the relation between the compressive strength and density of a 1-3 concrete; also between compressive strength and grading of aggregate as measured by fineness modulus. In the tests represented on this slide the consistency of the concrete and the mix were maintained constant. It will be seen that for these conditions there is a well-defined relation between strength and density as well as between strength and fineness modulus. The strength increases with increase in density and fineness modulus until a point is reached where the grading of the aggregate is too coarse for the amount of cement used. Beyond this point both strength and density decrease. For these tests the density ranged from about .70 to .85 and the fineness modulus from 3.00 to 7.00. The corresponding range in compressive strength was from about 2000 lb. per sq. in. to 4750 lb. per sq. in.

The next slide (Fig. 2) shows the relation between the compressive strength and density of concrete for wide variations in the mix, consist-

ency, and grading of aggregate. The mix in these tests ranged from 1-1/3 to 1-5 by volume. The consistency varied from 90 per cent to 150 per cent *normal* consistency. Three gradings of aggregate were used, the fineness moduli of which were 1.60, 4.50 and 6.00.

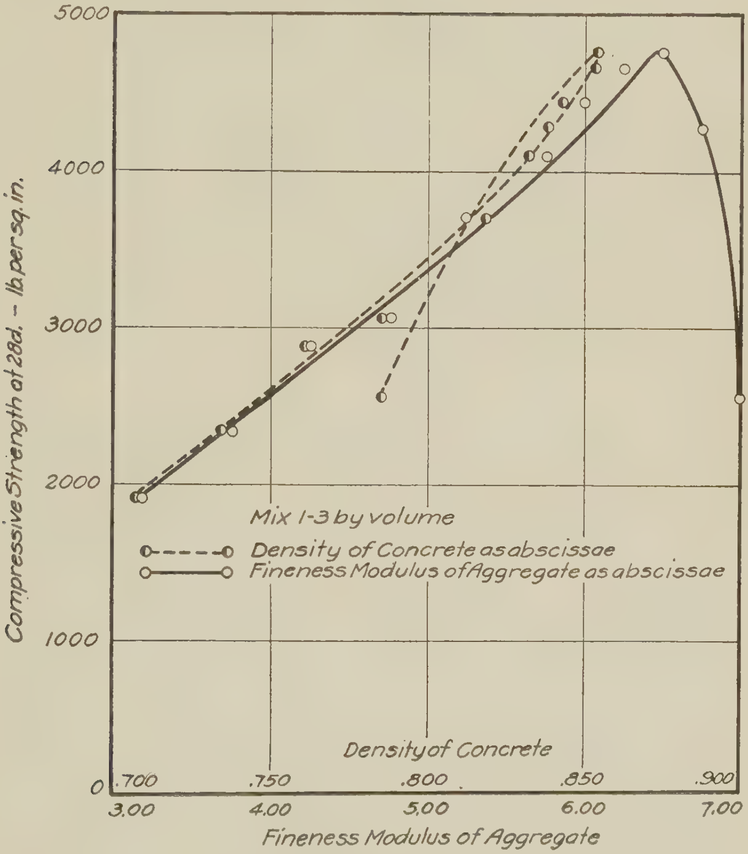


FIG. 1.—RELATION BETWEEN STRENGTH AND DENSITY OF CONCRETE AND BETWEEN STRENGTH AND FINENESS MODULUS OF AGGREGATE.

(Data from Series 76)
Compression tests of 6 x 12-in. cylinders.
Relative consistency 1.00.
Aggregate; sand and pebbles from Elgin, Illinois, graded from 0-1¼ in.
Specimens stored in damp sand; tested damp.
Each value is the average of 5 tests made on different days.

It will be noted that the rich mixes are lowest and that the lean mixes are highest in density. Mixtures of neat cement in this series of tests varied in density from about .50 to .55 depending on the consistency. The individual diagrams show that for a given mix and grading but varying

consistency there is a direct relation between strength and density. The individual diagrams also show that small changes in density may be accompanied by large changes in compressive strength. This is especially

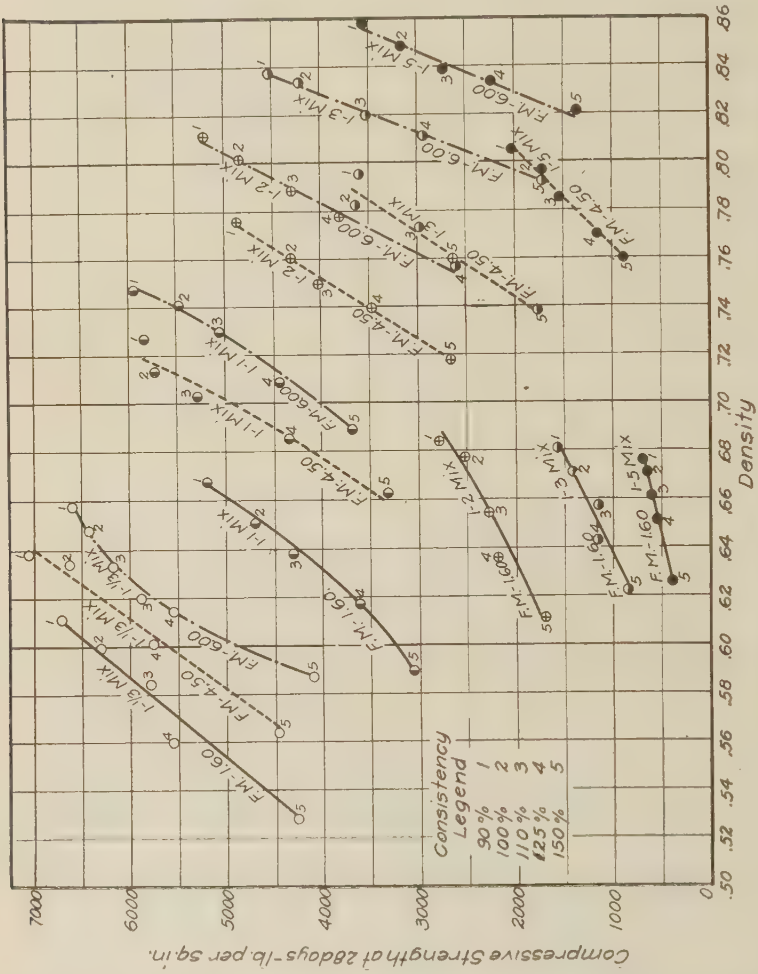


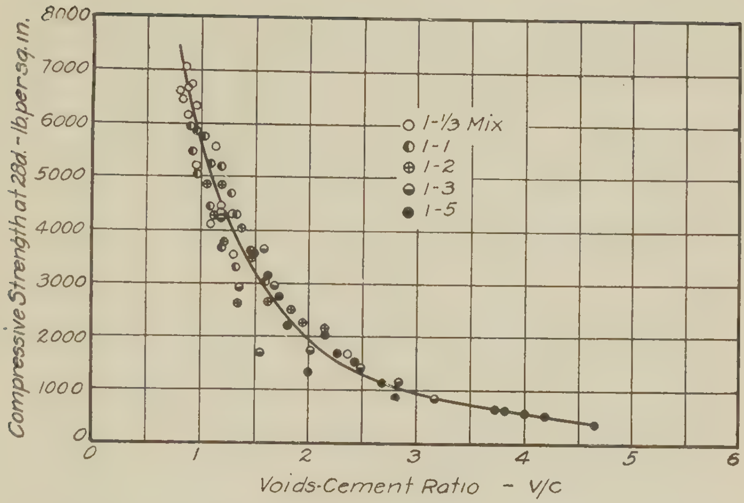
FIG. 2.—RELATION BETWEEN COMPRESSIVE STRENGTH AND DENSITY OF CONCRETE.

(Data from Series 83)

Compression tests of 6 x 12 in. cylinders. Aggregate; sand and pebbles from Elgin, Illinois. Mix by volume. Specimens stored in damp sand; tested damp.

Each value is the average of 5 tests made on different days.

true for the concretes made with the more coarsely graded aggregate. Concrete having a strength of 4500 pounds per square inch in these tests varied in density from about .54 to .84, and concrete having a density of about .65 ranged in strength from 500 lb. per sq. in. to about 6500 lb. per sq. in. It is evident, therefore that the strength of concrete cannot



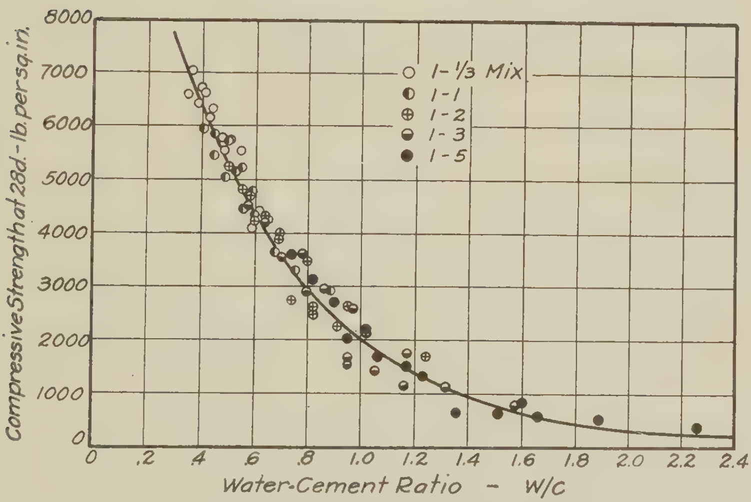


FIG. 3.—RELATION BETWEEN STRENGTH AND VOIDS-CEMENT RATIO AND BETWEEN STRENGTH AND WATER-CEMENT RATIO.

(Data from Series 83)
Compression tests of 6 x 12-in. cylinders.
Mix by volume.
Aggregate; sand and pebbles from Elgin, Illinois.
Specimens stored in damp sand; tested damp.
Each value is the average of 5 tests made on different days.

be judged by density alone when the mix, consistency and grading are varied over a wide range.

In the next slide (Fig. 3) data obtained from the same tests represented on the previous slide (Fig. 2) have been plotted to show the relation of water-cement ratio, and voids-cement ratio to compressive strength. The points which were widely scattered in the previous slide (Fig. 2) are here distributed fairly uniformly along the curves which show the general relation existing between water-cement ratio and compressive strength and between voids-cement ratio and compressive strength.

The following rules give briefly the principal points to be observed in order to obtain concrete of high quality:

(1) Use only aggregates which are clean and structurally sound.

(2) Use a sufficient quantity of cement to give a smooth working concrete with the aggregates to be used.

(3) Use aggregates which are well graded in respect to size of particles.

This item is important when impermeable concrete and concrete of high strength are desired. Tests made at the Structural Materials Research Laboratory show that for a given mix and consistency the strength may be more than doubled by varying the grading of the aggregate.

(4) Use as small an amount of mixing water as possible to produce a concrete which can be properly worked into place so as to give a dense, compact mass.

(5) Mix the concrete thoroughly.

(6) Handle and place the mixed concrete in such a manner as will prevent separation of the aggregate and secure a uniformly compact mass in the forms.

This item is of more importance than usually assumed. Careless handling and improper placing of the concrete subsequent to mixing will often minimize the benefits gained by careful grading and the use of the proper cement and water content.

(7) Provide curing conditions during the early stages of hardening of the concrete which will allow the concrete to harden normally and prevent it from drying out prematurely.

The effect of curing condition on the properties of concrete cannot be too strongly emphasized. Concrete which is permitted to dry out in the early stages of hardening cannot be expected to show much gain in strength with lapse of time. The effect of curing condition on impermeability is fully as marked as on strength, as tests made by Professor Withey at the University of Wisconsin show. If concrete of high quality is to be secured the handling, placing, and curing of the concrete which are often considered to be of minor importance must be given careful attention.

Mr. Chace. W. G. CHACE.—Pine and oak are two different kinds of wood, and each is good in its way. Concrete may be good either from the point of view of impermeability or compressive strength, and in many cases it is not

necessary that maximum strength be attained: for instance, gravity dams and specially heavy walls and foundations of buildings are commonly of greater size than necessary for maximum strength. Impermeability is very desirable in foundation walls; also in such structures as an aqueduct or a dam. It is a question of what you need, a question of the results which you are specifying.

F. R. McMILLAN.—Without wishing to detract from the answer of Mr. Gonnerman, I will state that for several years I have used four rules for making concrete which are easily remembered, and to a considerable extent cover what the gentleman has said: "Use as large rock as the conditions will permit." "Use as much rock as the conditions will permit." "Keep it wet as long as the conditions will permit." **Mr. McMillan.**

(D) Provision is usually made in all building laws for the maximum ultimate loading to which the concrete may be subjected in compression after it has attained its full strength. We frequently have occasion to apply loading to concrete which is only a few days old, sometimes by means of hydraulic jacks and in other cases by direct loading. We are always confronting the assumption that we are overloading the fresh concrete. What would be considered the safe unit stress in compression on concrete 24 hours old under normal conditions of weather and materials, assuming a 1:2:4 mix? What expedients other than those customarily employed can be used to increase the value of concrete in compression under the above circumstances?

A. R. LORD.—This question involves a whole array of controversial matters and any answer must necessarily be subject to disagreement. In the first place a 1:2:4 mix is not a strength specification and the values placed upon the strength of such a mix at an age of twenty-eight to thirty days in the building codes are frequently unreliable. The strength of concrete depends upon many factors of which the following seem to be especially influential. **Mr. Lord.**

(1) the water cement ratio.
(2) the void cement ratio.
(3) the quality of the materials.
(4) the temperature.
(5) the age.
(6) the moisture available for hydration.

With the limitation to a twenty-four-hour concrete, items (5) and (6) drop out under any probable conditions on a job, but items (1) to (4) are important even at the age of twenty-four hours. Under (3) the particular brand of cement exerts a very marked influence—some cements give much greater strengths at early ages and some are more retarded by low temperature than others. "Cement fondu" has been suggested to me as a possible advantage here.

To secure a high crushing strength of 1:2:4 mix at twenty-four hours under working conditions I should recommend (a) Use a cement that sets up quickly; (b) Use the minimum amount of mixing water, resulting in a concrete of very stiff consistency; (c) Mix the concrete at least 2½ minutes in a batch mixer; (d) Work the concrete thoroughly to expel any confined air; (e) Insure a temperature of from 70 deg. to 100 deg. F and (f) Maintain a humid atmosphere immediately surrounding the new concrete. This may sound elaborate but it is entirely practical and not unduly expensive on the job. Under these conditions I should predict a strength of from 400 to 500 lb. per sq. in. in twenty-four hours, or about twice what would be expected where no special precautions are used. A further increase in strength may be obtained by scientific mixing or grading of the aggregate which will permit of using a smaller water amount ratio and will reduce the final voids. I am assuming that special methods such as steam curing are not practical on the job.

With regard to the permissible stress in compression on twenty-four hour concrete, the precise nature of the loading is important. Probably the most frequent case arises in connection with remodeling or moving existing buildings. When but a small area of the concrete is stressed it may be stressed to a greater value than would be safe on the entire area. Formula (50) in the Joint Committee report dated June 4, 1921, may properly be applied to the case, using f_c' as the twenty-four hour strength. If one-eighth of the area is loaded this would permit a working stress of 200 lb. per. sq. in. (14 tons per sq. ft.) on concrete made and treated as outlined above. The presence of reinforcement may serve as a tie and permit higher stress if well arranged. If the whole area is loaded this stress should be halved.

All of the above discussion is based upon direct compression such as would occur in the foundation walls or columns of a building. If bending strength is involved the compressive fiber stress in the concrete may not be the governing factor but the strength will probably be limited by the bond of the fresh concrete on the reinforcement, which is very small at twenty-four hours. Many apartment hotel and office structures receive their greatest loads during construction but such loading rarely occurs at ages of less than one or two weeks. The ratio of the strength of concrete at any age to that at twenty-eight days may be averaged as follows (very approximate figures owing to the vast diversity found in the control exercised in making and durng concrete).

Percentage of 28-day Strength.

	Temperature	
Age	*Low*	*Normal Summer*
1 day	10 to 14%	14-18%
3 days	25 to 33%	30-40%
7 days	35 to 45%	45-55%
10 days	50 to 60%	60-70%
14 days	65 to 75%	70-80%

RICHARD H. CATLETT.—Mr. Lord has left out any mention of the addition of accelerators for getting his strength in 24 hours. I just had a case in which a caisson was being pushed down through quicksand and water, in which plain concrete requires three days to get its proper strength, and by the addition of 8% of accelerator, we were able to cut that down to 24 hours. I do not believe it is fair to neglect entirely the possibility of accelerating the early strengths by the addition of recognized accelerating materials.

(E)—Is the value of integral waterproofing pure psychological in its effect on the contractor?

S. C. HOLLISTER.—I did not propound this question and I have been in a considerable quandary as to exactly what was meant by the psychological effect on the contractor. As nearly as I have had it explained by those who seem to think there is such a psychological effect, it is that mental attitude of carefulness produced when the contractor or his foreman is obliged to use an integral waterproofing compound, the instructions for the use of which are to the effect that concrete of very high grade must be made in order to use the integral waterproofing compound. That is the intent, as I get it, of the question being put in this form. Mr. Hollister.

Personally, I attack this problem as some one seeking the light of day. There is no answer adequate as yet on the matter of integral waterproofing compound. Certainly those who produce the compounds and those who use the compounds are both entitled to more information upon the results and upon the benefits where they occur.

Integral waterproofing compounds are those compounds which, for the purpose or for the intent of waterproofing the concrete structure, are added to the concrete mix in order to produce such attempted waterproof effect. These compounds divide themselves rather naturally into three groups. The first is natural compound which is inert, which has no chemical reaction upon the other ingredients in the mix. These compounds include such materials as diatomaceous earth and infusorial earth, volcanic ash, clay, calcium carbonate where it exists in its natural form, etc.

A second group includes other materials which are inert and prepared by mechanical means, such as by grinding. Among those compounds may be included finely ground silicious material, ground tufa, ground limestone, and materials of that nature. It might be pointed out right here, however, that this class of ground materials has been surrounded by considerable doubt as to whether there is perhaps some chemical reaction with the cement during the setting process. Some of these ground materials, for instance, ground silica, is alleged by some to have some chemical reaction with the cement.

The last group is the material prepared through chemical processes. This includes pulverized slag, hydrated lime, insoluble soaps, hydrocarbon

emulsions, calciuf chloride, ocychlorides, ammonium stearates, ammonium resinates and algonates, etc. This other class tends to render the particles of the aggregates and the pores of the resulting concrete water repellent or water resistant by virtue of the nature of the surface that is produced upon the particles by the ingredients put into the mix.

The purpose of waterproofing a structure is perhaps not altogether clear. A structure can be made of portland cement concrete which in itself is water tight, provided two things: provided that the surrounding conditions are ideal and provided also that the construction, the actual mixing and placing of the concrete is likewise ideal. There have been many instances of very high grade, satisfactory structures made with portland cement concrete so far as water proofing is concerned. There arises the difficulty, however, that in the case of work imperfectly performed or in a case where there are difficulties unforeseen which develop cracks, then a type of waterproofing is desired which will not only waterproof the concrete but will waterproof the structural defects. The engineer must decide in his own mind what type of waterproofing he is going to use in order to overcome the type of defects he may expect in the particular work.

There is another effect which, according to some, integral waterproofing is said to produce. Ths effect is an increase in workability for a given consistency. I will not say that this is a fact in all cases, although it is certainly in some. I am searching for data, the committee on waterproofing is searching for data, in fact, it is searching for data on all those points.

I want to be understood as being thoroughly openminded in my approach toward this problem, and not biased by one side or the other, because what we need is exact information as to what the result may be. Certainly I do not feel that if the psychological effect is the only result obtained, it necessarily should be given a large amount of weight for any material, whether waterproofing or not.

Mr. Chace. W. G. CHACE.—On the Winnipeg aqueduct we had occasion to build concrete which did not require very high strength. We made laboratory tests to determine our aggregate mixture, which showed that with a moderate percentage of fines of a silicious nature or limestone nature, we were able to get a thoroughly watertight mixture with one barrel of cement per cubic yard of concrete. The average consumption of cement on that job, on account of the low strength required, was not over 1 1/4 bbl. for all of the work, and we have no leakage from ground water or loss of water through the walls of that concrete. That is a pretty general statement, but I can verify it by test results which indicated that of 100 gal. of water taken into that aqueduct 96 miles away from its delivering point, we were able to deliver 99.5 gal. Those who sold waterproofing at 8 and 10¢ a pound in Canada wanted to sell us a lot of it, but we decided we could do better with fine sands. We found a pit in which that material was present.

The pipe makers were up against it all the time on another job at Denver; we could not get anything but what is common on the prairies—a gravel or pea gravel material—and in order to get our sand we put in an ore grinder and passed our sand through that grinder, thus reducing a certain proportion of the sand to a dust, which gave us satisfactory results as a "tightener."

(F). How can laboratory tests which are now being made with regard to consistency of concrete be put into practical use?

W. A. SLATER.—In order to arrive at a basis for discussing this question at all, we have to assume that laboratory tests that have been made and are being made, have led to a standard measure of consistency although this may not be the case at the present time. There is very little, I think, now that can be said that has a general application, and I am going to make what I have to say very short, after which I believe H. A. Davis and R. B. Young have been requested by the Secretary to give their experiences on specific cases. I think that is the kind of answer desired by the men who asked the question, and without having had that specific experience, I cannot answer it. Mr. Slater.

There are two places, I think, for the use of a measure of consistency; one is in the determining of the proportions which are to be used in the concrete; and the other is in the inspection of the concrete after the proportions have been determined upon. I can only make a very imperfect illustration of those two things. Let us suppose that in a given case the aggregate has been decided upon. Let us suppose also for illustration that we accept the water cement ratio, as the criterion of the strength of the concrete. If the water cement ratio is 1.0 the water and cement may be mixed in the form of a paste of equal parts of water and cement. With the aggregate already determined upon the cement paste may be added to the aggregate until the desired consistency is reached.

That is an application stated as briefly as I can, in determining the mix in the laboratory. When it comes to the field application the only general thing I believe that can be said for a measure of consistency is that it affords a measure that determines whether the conditions aimed at have been reached. I know that we will meet with objectors on that score who say that the variation in the water, in the sand, from time to time will throw out all value of any consistency measure. Possible so in many cases, but if we have, as I assumed in the first place, arrived at what we will agree upon as a measure of consistency, we have a means of measuring the magnitude of these variations and determining when they are so great that improvement must be made also of judging when an improvement has been made.

In making an estimate of the quantity of concrete or of whether the thickness of a floor has been met by the contractor, we do not guess at

the dimensions; we get a rule and measure the quantity of concrete or the thickness of the floor. In the same way, when it comes to a matter of inspection, if it is going to be satisfactory inspection, there has to be a measure which will be agreed upon to be conclusive. This much is fundamental and I believe that the effort to reach a standard measure of consistency will justify itself in the end.

I do not believe that I can say anything more that is generally applicable to all cases, any more than one can say how a contractor's plant should be laid out unless he knows what kind of a structure is to be built.

Mr. Davis. H. A. DAVIS.—My remarks are based on the experience gained incident to controlling the consistency of the concrete used in the construction of concrete ships for the Emergency Fleet Corp. The cylinder slump test was the apparatus used in controlling the consistency.

Prior to the first concreting operation at any of the yards preliminary laboratory studies had been made of such factors as the aggregate actually to be used at that yard, similarly the cement to be used at that yard, the tests of concrete containing these aggregates and cement being over a wide range of consistency.

At each yard sections typical of the construction to be concreted in the ship were built and in cooperation with the contractor and in recognition of the difficulty of the work the maximum limit of slump was decided upon.

With this as a background, the field procedure was as follows: The contractor provided an accurate method of measuring the water at the mixer, the simpler the better. It generally consisted of a barrel with an angle pipe overflow set in the side so that it could be easily adjusted. The second step was to make someone in the contractor's force responsible for changing the amount of water used at the mixer, generally this was not left to the mixer man but the concreting foreman or his assistant.

When the concreting operation started the water measuring device on the mixer was set to give concrete with the desired slump. I may digress for a minute to say that the preliminary tests of concrete to be used at the yard were sufficiently diverse as to consistency so that the inspector knew what was a reasonable enforcement of the slump test so that this action was not purely arbitrary. With the water mixed in proportion to give concrete of the desired slump, the procedure was relatively simple. The inspector made slump test determinations at frequent intervals about once an hour and made a permanent record of same. Further the inspector watched the concrete as it was going in and any change in the consistency that was apparent he immediately checked by the slump test and changed the amount of water added at the mixer if necessary, that is called the attention of the party responsible to the fact.

That is about all that can be said as to procedure; as to results accomplished it resulted in two things. Generally when the contractor's viewpoints were given proper consideration and he was given the opportunity of trying out the workability of the concrete that he was supposed

to use, we were in accord that if the concrete delivered were maintained uniform a better job would result, so that after the beginning of the concreting operation the slump test functioned as a means of securing uniformity in the delivered concrete.

Further in concreting some fourteen ships at some seven yards the uniformity in tests of the resulting concrete was very satisfactory and in every case above the minimum strength that was deemed required by this type of construction.

R. B. YOUNG.—We considered methods of controlling the consistency in the field in connection with the Queenston-Chippawa Power Development of the Hydro-Electric Power Commission of Ontario. We studied the problem and finally decided that we would not use any test for consistency. The slump test which we considered was found to be impracticable with our conditions for we were using lean mixtures, seldom richer than 1 : 2 : 4, the majority 1 : 2 : 5, or leaner and crushed rock aggregates graded up to 2-1/2 inches. We overcame the necessity of measuring consistency by limiting the amount of water which could be used per bag of cement. If the proportions of cement, sand, stone and water as originally set did not yield a consistency of sufficient workability to suit the construction forces, they were permitted to increase the amount of water as they saw fit but the increased water had to be compensated for by increased cement until the quantity of water per bag of cement came within the limits set. **Mr. Young.**

We had very little trouble with the question of consistency when that method was followed. At times the consistencies were wetter than the engineers would approve of but because of the increased use of cement, the tendency was to use the driest practical consistency at all times.

We have also made a good many tests upon the flow table but we can not see that it is practical to take into the field under the usual field conditions.

We had very little with honeycombing. Our mixtures were not dryer than those used on any similar job where the best modern practice is being followed. The mixtures were at all times sufficiently plastic to be handled in chutes and to be placed easily in the forms.

(G). Rusting of steel reinforcement in concrete construction causes the breaking or spalling off of concrete and otherwise injures the work. What is the best method of keeping the steel from the exterior surface? How much protection is necessary? What is the best way to make repairs where this damage occurs?

M. M. UPSON.—We all know that the deterioration of steel in concrete gives us possibly more concern than any other phase of reinforced-concrete construction, and yet I sometimes wonder whether our engineers and builders, as a whole are as yet sufficiently *alive* to this danger. **Mr. Upson.**

As Chairman of Committee E-6 on Destructive Agents and Protective Treatments, I have been studying our sick babies pretty carefully and find that the mortality is alarmingly high. First, I think that we, as engineers, are not careful enough in our designs. I was interested this morning in observing the slides and listening to what was said on the subject of stadiums. In all the details discussed, so far as I was able to gather, no mention was made of expansion joints. Now all of us who look for weaknesses in a concrete structure in these days first examine the expansion joint to see whether it is standing up well. Experience has taught us that this is the location where trouble usually begins.

The solution of the problem comes to the engineer and designer. They must remember that contraction and expansion exist in every structure, and must visualize clearly just how this action is going to affect their particular problem. Next the contractor (or builder) must cooperate with the engineer in giving him the advantage of his experience not only in care of execution, but also in cooperating in the attaining of a proper design.

It must be remembered that an impervious concrete is required to protect the steel. The amount of the covering depends on the character of the concrete and on the moisture conditions to which the surface is subjected. The roof or wall of a steam room or dye house should necessarily afford greater protection to the steel than that of an office building or dry storage. Likewise, the exterior of a building, particularly in a damp climate, should have a greater thickness of concrete over the metal than the interior.

Care must be exercised in the execution of work to see that the steel is rigidly held in place so that no part of it touches the surface. This is generally pretty effectively done by using small blocks of concrete to brace the bars well away from the forms. A mistake is frequently made in providing these blocks of too weak a mixture or not of sufficient density to keep the moisture out properly. The "doughnut concrete," as it is sometimes called, is used in much the same manner as the block. The binding of steel together is helpful in that it maintains the rods in a positive position so that the splicing and the tamping of the concrete do not displace them.

All these methods are so well known that it seems unnecessary to do more than call them to your attention.

The next question is how much protection is really necessary. As already indicated, the answer may vary widely due to the conditions and character of the concrete that is used. I have been interested recently in comparing the attitudes of different engineering bodies on this much discussed question. The most authentic and scientific observation that I have been able to find is made by the Institution of Civil Engineers of Great Britain in a report that has recently come out from a committee appointed some five or six years ago to inspect and report on all structural materials which are used in harbor construction. That committee has made its

first report in a book of recent edition which contains some worthwhile information. Their conclusion is that steel from 1 1/2 to 2 in. back from the surface is perfectly good for harbor work construction. This is predicted on a mixture of not less than 1: 2: 4, and usually 1: 1 1/2: 3 1/2.

The Bureau of Standards in its report has made a specification that the steel should be covered by 2 in. of concrete when used in sea water. The Joint Committee recently has placed this at 3 in. With this information before us, we can choose to meet our fancy. Unquestionably, the answer lies largely in the quality of the concrete and its exposure. Steel below low water in concrete can be very close to the surface without deterioration; steel between high and low water should be well covered. It must be kept in mind that there are practical limitations to the amount of covering over the steel in the design of precast members or in members which are subject to flexure. If the steel is too far from the surface, any bending of the member produces small cracks, which make the concrete permeable. Furthermore, the moving in of the steel brings it so near the neutral axis that the member has insufficient strength to be handled. In other words, there are limitations to the factor of safety, which can be used in determining the thickness of the concrete coating.

"What are the best ways to make repairs when damage occurs?" I lean very strongly towards the use of the cement gun, where it is practicable. There are two reasons: One is that it is possible to make a good job of cleaning by using it as a sand blast first, thereby removing all foreign matter, oxidation, disintegrated concrete, etc., so that one is certain that the patching is being done on good material; the other is because, when properly handled, the cement gun provides a very dense coating which is impervious to the action of moisture. Of course, there are an infinite number of other ways by which this can be accomplished.

W. C. SPIKER.—It happens that I have had some very intimate experience in protecting concrete where it was honeycombed or otherwise defective. It happened that I not only had charge of designs of concrete ships, but also had charge of building some. In the case of building the ships, we were squarely up against the problem of protecting the steel if it was exposed after the work had been poured. You have already been told to what length we went in getting a consistency. We went to pretty near every length there is to get the concrete into the forms and around the steel. As you probably know, we had up to four percent, and sometimes more steel to cover and very little concrete to cover it with, so it is not surprising that we had some difficulty or at least had a big problem to solve in covering it so that it would stay. As the gentleman who preceded me said, we found that the concrete gun was one of the very best methods of covering it where there was a large area exposed. We had a great many areas which were too small to cover with the cement gun. In those cases, we thoroughly cleaned the void with water and then actually caulked the hole, that is we drove concrete into the opening. Now the secret of getting it to stay there, aside from getting the hole clean

Mr. Spiker.

and driving it in, is properly curing it. We had a great many that were not successful, but eventually we found that if the work was done well and then kept sufficiently wet long enough, that after the work was finished you could not tell where the defects were; in other words, the work can be done, but it takes time, trouble and expense to get it done. While I am on my feet, I would like to refer to a question, a practical question rather than a theoretical one, and in bringing it up I am bringing it up largely for my own information. If there is any one in the audience who can help me on the problem, I would like to have them call on me after the meeting. The big problem that I have is to get concrete mixed right. There are so many different kinds of mixers and so many different salesmen that have the only mixer on the market, and they sell so many kinds of mixers to so many different contractors that I am always up against the trouble of getting the concrete well mixed. That perhaps is not a theoretical question, that is a practical question, but I do not see any reason why this Institute cannot put out some propaganda or papers that will help to get it before the public that we need better concrete mixers as much as we need anything else. Thank you.

(H) What protection should be given to reinforced-concrete construction during severe winter weather to prevent injury to the work?

(No discussion)

(I) Is it better to install cement fill and finish before or after plastering is done?

(J) What methods have been found successful in making concrete floor finish set up quickly in cold weather?

(K) The advantages of during monolithic floors by keeping them wet has never been realized by or brought home to building contractors as they have to road contractors. A discussion on how to get a hard non-dusting concrete floor would be helpful.

(L) What is your experience with the use of chemical hardeners for preventing dusting of concrete floors and to improve waterproof qualities?

Mr. Loney. N. M. LONEY.—The first question is really not a question that comes before this assemblage very much. I think it is largely a commercial question. Both the floor and plaster and trim are capable of being repaired afterwards, and it is a question of which fellow is going to be the goat, and I am going to pass that question without further remarks.

The second question, what methods have been found successful in

making concrete floor finish set up quickly in cold weather? The ordinary method, which I presume everybody resorts to at times, is the use of some preparation of calcium chloride, either under some of the various trade names by which it is sold, or the preparation of solutions on the job, and the use of hydrated lime is sometimes resorted to, and of course in cold weather, hot water and the heating of the aggregates are various other devices resorted to. I want to say that notwithstanding the doubt which seems to be cast on the quality of concrete in which admixtures are used, that as a practical matter I believe that we are well justified in resorting to their use. For instance, in cold or cool weather, the use of an accelerator on cement floor finish enables you to more or less definitely fix the time at which your masons can get to work on the floor; whereas if you leave it to the course of natural events, it may be midnight or later when your men get at the work and you get a correspondingly worse job than if you took a somewhat less strength of concrete and controlled your operations better.

The next question as to the means of bringing to people's attention the necessity of proper curing—it is a matter the necessity of which is recognized by everybody and I presume that the reason it is not more generally carried out is that, to start with, the owners are unwilling to give the builders time enough to properly cure their floors, and in some cases unwilling to stand the expense. As a general proposition, a cement floor is used only because it is the cheapest floor which will serve the purpose, and that being the case, the desire seems to be to drive the cost down to the last possible elimination of expense, and specifications as they are ordinarily used on competitive work, practically compel the use of an unsatisfactory floor and a good illustration of this is the construction of buildings with ordinary monolithic finish. I am speaking of industrial buildings, almost requires that the forms be constructed within twenty-four hours on a freshly finished surface. Now the men who wanted to put in a good floor, if he stuck to his principles in that case, would never get the job, so I believe it comes back to a question of educating owners, engineers and architects. I believe all contractors admit this to be the case, and often against their better judgment, have to resort to practices they do not approve of.

Now the last question, "What is your experience in the use of chemical hardeners for preventing dusting of concrete floors and to improve water-proof qualities?" I do not see that those two questions are related. The question of waterproofing a cement floor finish in my experience has rarely come to the front, but to prevent dusting, according to some investigations which the Committee on Cement Floor Finish has made and called for—there are about thirty patented articles, so-called liquid hardeners, on the market, the majority of which have as a base magnesium fluosilicate in various quantities or silicate of soda or zinc sulphate, and possibly others that I do not know of, also ordinary soaps which gum up the floor and tend to fill up the pores and little irregularities. I would say that

all of these articles have some merit, especially on floors which are not defective enough to require replacing, and still are not perfect. It is my private opinion that none of them are absolutely necessary if the proper conditions which I referred to a minute ago exist and proper workmanship, etc., are used, and I think that a floor can be produced which cannot be improved by the addition of these materials, but I do believe that all of them have some beneficial effect when used on floors which are somewhat defective.

Mr. Bloecher. W. P. BLOECHER.—On one of our recent jobs we were called upon to use liquid hardeners of two different kinds throughout the entire plant. It was a large plant, possibly 800,000 sq. ft. of floor area, and we did not make any exhaustive tests on what the hardeners did, but we did go to the expense of getting hard steel center punches and scratching around, and the extent to which the hardeners did good work was very marked. The two types of hardeners were different priced; one was about twice as expensive as the other, and the extent to which you could scratch it with the steel center punch also showed up in the price, that is, the most expensive hardener scratched with great difficulty, the less expensive more easily and the untreated floor very easily indeed.

Mr. Ashton. ERNEST ASHTON.—About three years ago we were called in by some friends of ours in Philadelphia to give advice to getting dustless floors in a large garage. We succeeded in persuading them that if they wanted to have dustless concrete floors it was necessary to allow the contractor sufficient time to do the work, and secondly, it would be rather expensive but would pay in the long run. We suggested the use of calcium chloride in the concrete finish, the use of graphite chips in proportion to give a reasonably dense mixture, and then the coating of the finished job after being poured for ten days, with three coats of sodium silicate. I think possibly the job is the best in the United States today of a concrete floor. It depends on whether the owner is willing to pay the price.

[Answers to Questions M-Q were sent out to the respective discussors but were never returned corrected. They are, therefore, omitted here.—EDITOR.]

(R) Why does the average contractor use a batch in preference to a continuous mixer?

Mr. Ahlers. J. H. AHLERS.—Continuous mixers have never been very practical in building construction work. What we have a mixer for is to get good concrete. The objection to the continuous mixer has always been that you have not been able to control the batch. I am not going to discuss the quality of one mixer vs. the other. I believe this should be a matter of test and something that a mixer man perhaps can answer.

The governing factoi in the question of continuous vs. batch mixers, is the mechanical operations and conditions. Most mixers on building

construction are to make concrete that will be elevated above the point of mixing. Therefor, it is desirable to get it out in batches and hoist it up and place it in such. The continuous mixer would not be practical for that sort of work. I do not believe there is anything further to gain by a discussion of this subject unless some mixer man may have something to say on the subject.

(S) Is the use of premixed aggregate now on the market and in common use in some cities to be encouraged or discouraged for concrete structures of small sections such as occur in building work? Is the use of premixed aggregates economical? What are their other advantages and disadvantages?

(T) What is the range of variation in the grading of premixed aggregates at the time it enters the mixer? What is the effect of the above variations on the yield, cement factor, water cement ratio, density and strength of the resulting concrete? Are these variations sufficient to necessitate correcting measures, and if so, what is the best method of determining and making corrections? Where are the comparative costs per cubic yard of concrete made from mixed aggregate and separate aggregates?

J. G. AHLERS.—I believe that ready mixed aggregate should be encouraged for construction work, because it has proven economical and is getting to be used more and more in sections of the country where it is found naturally in fairly good proportions, and in places where pains have been taken to reproportion aggregates; I believe this a case where, like lots of other things we hear about, it is getting better and better day by day in every way. I believe that anything that is good and economically sound, in the end will win out, and the proof of it will be just that. I believe that when measuring the aggregate going into the concrete on the work, if you have only one bulk to measure, you can get as good or better results as if you have two separate aggregates to measure and place in your mixer. Now the second question, as to the range of variations at the time it enters the mixer:— Mr. Ahlers

The curves that I will show with the report to-morrow will give the variation in aggregate between the time it was out on a boat from the dredge and the aggregate just as it was coming out of the gates and going into the mixer, showing a great improvement in uniformity. The variation in cases is smaller in percentage of fineness modulus than the percentages in strength of the cylinders, whereas those samples, taken at the point of loading from the dredge had a very large variation. Corresponding tests taken of sand and gravel, separate ingredients taken by me personally at the dredge were unfortunately delayed due to bad weather. The Hunt

Laboratories are now running those tests with instructions to hurry them through and I hope to have them tomorrow to show on lantern slides.

From information I know that they will show greater variation at the time of taking on the dredge than the time it was taken at the mixer.

One other question, "How corrections can be made at the time of mixing?".

The very fact that there is some uniformity of premixed aggregate as it goes into the mixer enables you, if you have taken one sieve analysis, to make a continuous correction which will bring it up to the desired fineness modulus. This can be done either by having a separate bin, like we have on the building operation on which the tests were made, or else charging from the sides with wheelbarrows in definite quantities to each batch.

Another question asked is about the difference in the cost. This also is altogether a matter of opinion. Mr. Loney and I for instance, do not agree on the factors entering into the computations to arrive at comparison and we have discussed that in detail. Mr. Dixon of the Turner Company and I too, are at variance due to the fact that we make certain assumptions as to yield that no definite tests have been made to settle. It is my intention to make some tests this spring, but these will vary in accordance with the aggregates used.

The swelling when mixed with cement or increase in volume is the governing factor as to the difference in cost. Under conditions existing on an operation in New York, it will give the cost of separate gravel and sand with handling charge added \$3.33 per cu. yd. at the time it goes into the mixer as against a cost of ready mixed aggregate, including the handling of \$2.81 a cu. yd. That is a difference of 52¢ which on 400 yd. would amount to \$2,080. Besides an additional sum would be saved in plant installation on ready mixed aggregate.

Passing on to the next question, whether, for small sections, it is desirable to use premixed aggregate, I do not see where any distinction can be made because the maximum size of the aggregate has as much effect in separate material as in ready mixed aggregate. If you have a minimum section of 2 in. as in tin pan construction and some of the two way block systems, you could not use anything larger than 3/4-in. maximum size and so on up to a slab of 9 in. thickness. Here you could use a size of 1 1/4 in. What we are after is to use the larger size of aggregate in order to get as high a fineness modulus as possible.

Separate Group Meeting for Those Interested in the Manufacture of Concrete Roofing Tile.

Chairman Leslie H. Allen.—The tile business is just beginning to make rapid strides and therefore the Directors of the American Concrete Institute thought it would be well to call a meeting of those interested in the product as manufacturers or users to talk over the problems of tile manufacture. They are not by any means solved. Quite a lot of our difficulties are partially solved,—solved to the point where we can say the roofing tile business can and should be a successful business. So it is very well worth while that the makers of roofing tile should get together and discuss their problems. Some of the largest producers of small concrete roofing tile for residence work, manufacturers of machinery and several other gentlemen interested in the technical problems are present and we shall do well to discuss fully and frankly the difficulties and problems that we are contending with. The difficult problem of color, whether applied dry or wet, whether you should use colored aggregates, and the problems of strength and water proofing, and methods of laying and so on. **Mr. Allen.**

Let us start with color, which I suppose is the most important. Let us hear from some of you gentlemen who make roof tiling, whether you use dry or wet color, and how you put it on, and whether you have any trouble with fading and what causes the fading and so on.

Henry Barneskan.—I put in 7 lb. of cement to 1 lb. of color and 6 lb. of fine screened clean river sand passing a 30-mesh screen. It is ground in a mill for an hour and applied dry, but I mix the concrete as wet as it will possibly stand up. This color is sprinkled on the surface, I put the sand in for a binder. It makes the color a part of the tile itself. I put them on racks and the next day they go into the curing room and the next day they are knocked off and stacked up. I have found that the tile bloom out if I let the temperature in the shop get below 45 deg., but if I keep it between 45 and 55 deg. I have never had any tile bloom out yet. My curing room is a solid concrete building. Inside the wall 6 in. are wall radiators on racks that are built into the wall. Those wall radiators run all around the curing room, and inside that again, inside the radiators are four thicknesses of heavy burlap with a stream of water running continuously on them, and I force the heat through the radiators through that damp burlap and into my tile. I have tile that has stood a test of 319 lb. before breaking. This room has ventilators in the roof. I maintain a temperature not exceeding 55 deg. and not below 45 deg. If it gets too hot it has a tendency to check the color on the face and you can rub it off. It will fade a great deal quicker when you put it on a roof. After the twenty-four hours curing is up, they are put right out in the storage room and left for seven to ten days until the curing process is over, and then I sprinkle water on them in addition to what they get from the burlap. We regulate heat by the ventilators. We can shut that off and get that room **Mr. Barneskan.**

Mr. Barneskan. down to forty in the summer time, with the cold water that is running in there. My color is mixed with cement and sand in a round drum containing five steel rollers an inch and a half in diameter.

Mr. Iggberg. F. W. IGGBERG.—I have used dry color mixed with cement about two and a half to one in the red, and the green about five to one.

Mr. Barneskan. MR. H. BARNESKAN.—My green mix is six to one and to every batch of color that is mixed you take one half bag of cement and a seventh of that in color and five-sevenths that in sand, and then put in that a half pound of pulverized copperas in the green. I mix the aggregate with a solution composed of sodium, copperas and litharge all through the tile, but where we are making a green tile I put in a pound and half of copperas ground up in the same mill to a batch of color, and I will say I have as green a color as I have ever seen. The object of adding copperas is to get a very green color. Take copperas and dissolve it in water, and it first looks brown but stir it long enough you get a very fine green. I think the copperas tends to fix the color. I tried to use calcium chloride to color my tile but it burnt little white blotches in the top of my tile.

Mr. Iggberg. MR. IGGBERG.—First we tried mixing out cement and color, and then we mixed water into it and mixed that in very thoroughly and then applied the top coating of this mixture fairly thick on the top of the tile, and since we have used that process we are unable to find any change in the color. I mix the color and cement very carefully, in portions of two and a half to one and five to one, and then I mix that with water until it flows fairly free not as freely as thick cream, merely so it will flow by its own weight. I use an arrangement of double trowelling bars on an automatic machine and have a funnel centrally located between them. I move the trowel bar on the moving tile underneath. The two trowels keep the color from flowing away.

Mr. Allen. CHAIRMAN ALLEN.—Is the quality or the result of color determined by chemical purity, or fineness of grinding, or specific gravity or what is it? What does a purchaser of color look for?—what tests can he apply to it?

Mr. Iggberg. MR. IGGBERG.—I have asked many different men that very same question without satisfaction but it is necessary to get scientific investigation. We have found one day we will get good results and the next day bad results from the same color. We have tried green colors that have been guaranteed pure chromium oxide, and one gives us one result and another an entirely different result. Why, I don't know. We ought to have some means of testing the material and know we are getting first class color. This will require a very thorough investigation and cost lots of money, and it is my suggestion that that be done. My company is willing to start the ball rolling.

Mr. Witherow. MR. WITHEROW.—My experience with colors is that you are obliged to analyze your colors in order to be positive you get the exact color you want for the exact purpose for which you are going to use it. For instance in our colored cement, we specify to the color manufacturers we want it lime proof, that is not affected by the lime in the cement. The way we deter-

mined this lime proofness was by experiment in our chemical laboratory. By using it with our white cement. The tests covered quite a lengthy period of time. We got colors from a dozen color concerns and we finally settled on one color manufacturer in New York City, from whom we now get all our colors. These colors have proven positively they do not fade under the most severe conditions when used in connection with our white cement. Our chemist makes tests on every color we use to determine if it is lime proof. Mr. Witherow.

CHAIRMAN ALLEN.—What is there in color, that is affected by lime,—is the cause chemical or physical? Mr. Allen.

MR. MULLENCAMP.—I have been told that many colors contain gypsum, as a filler, if this is true it can be detected by the use of hydrochloric acid. This is the test chemists have made. Colors should have a high degree of purity but a good many do not. I have found some containing gypsum. Mr. Mullencamp.

MR. IGGBERG.—We once had two samples analyzed and both were pure, but we had a great deal of trouble with certain colors in the past, even when two shipments of color contained the same kind of impurities or the same percentage. You can buy ninety per cent pure red oxide, where one of them will not have half so much color as another. Mr. Iggberg.

CHAIRMAN ALLEN.—Possibly a difference in the specific gravity of the two samples caused this variation. If the specific gravity of cement and pigment is far apart—the lighter material may rise to the surface and dust off. Mr. Allen.

There is no doubt that red oxides derived from different mineral sources, having different chemical constituents may give very different results. I understand that red bole, red haematite, and red ochre are all used to produce the red pigment sold as red oxide.

A German paper quoted in *Engineering and Contracting*, page 532, May 31, 1922, reads as follows:

"The best red colors are produced by red bole, a natural oxide of iron whose tint has been developed by fine grinding and calcination. It is largely used as the basis of red oxide paints.

"Several varieties of iron oxide are available, they vary considerably in composition, according to the amount of combined water present. The color does not appear to be directly related to the chemical composition, but rather to the size and density of the particles.

"One of the best forms is a by-product in the manufacture of sulphuric acid from calcined pyrites, but for use with cement it should be free from sulphurous acid, which is a common cause of scum and discoloration.

"Ochre is the chief material used for the production of a yellow color in cement work. It is a weathering product of ferruginous felspar and of very variable composition. It is usually kept for several years in the open, then ground and levigated so as to separate coarse impurities. Umber is a darker color, but in many respects similar to ochre. Both ochre and umber reduce the strength of the cement mortar or concrete.

Mr. Allen.

"Zinc chromate is sometimes used as a yellow pigment, but its price is generally too high for its extensive use in concrete or cement work.

"There are two chief sources of black pigment suitable for use with cement, namely manganese black and carbon black. Manganese blacks consist chiefly of manganese dioxide, while carbon blacks consist of slate, black shale or some form of soot, such as lamp black.

"Ground coke is also largely used as a black pigment. All these materials must be particularly finely ground. Usually manganese black is more serviceable than carbon black, but is more costly.

"Greens and blues are made from ultramarine with some other pigment such as chromium oxide, ultramarine increases the strength of the cement on account of the free (colloidal) silica and aluminum present which gives it hydraulic properties.

"The best green pigment for cement mortar is chromium oxide prepared from a mixture of potassium bichromate and sulphur.

"Lime green is a magnesium alumino silicate (augite) containing some iron and of a very variable composition. Most green cement mortars or concrete fade on account of the oxidation of the iron present."

From a Committee report of the British Concrete Institute, October, 1913. I quote as follows:

"Venetian red and Indian red should never be used, as they are heavily loaded with calcium sulphate, which often causes cement to disintegrate. Red haematite, some red ochres, and many other iron ores, particularly if burnt are safe and suitable. Red haematite has a very powerful effect, very little being needed. Yellow ochres are suitable and safe and have considerable coloring power. Burnt umber is safe and gives a nice warm color. A satisfactory color has not been found in blue or green. Copper arsenide gives a fair green, but it is not desirable. Ultramarine is unsafe. Black oxide of manganese is probably best, but it is not possible to get clear black. Ground hard-burnt coke may be used, but it is not so good. Ground coal or lamp black are quite unadmissible."

Mr. Mullencamp.

MR. MULLENCAMP.—Among people who manufacture colors for dyes, it seems to be the idea that the permanency of the color depends somewhat on the method of use. Exactly the same proportion of materials may be put into a combination, but unless the proper process is used to unite them permanently, the colors will not be permanent. If two men buy the same color and apply it to a product in different ways, one might get a good color and the other not?

Mr. Iggberg.

MR. IGGBERG.—I have heard of experiments being made with crushed clay roofing tile. One man producing gray roofing tile used haydite (burnt clay) aggregate. Clay tile and clay building brick is used for coloring the asphalt shingles, but that doesn't give us good color.

Mr. Mullencamp.

MR. MULLENCAMP.—I used crushed and burned fire clay tile to color aggregate in bridge work, and it was all right for three or four years, but it looks like the small-pox now. I never show the photographs of these bridges.

M. G. WATKINS.—I have been trying to figure out some process for the mixing of color. We are mixing by the Danish formula, and we use five pounds of color to a sack of cement,—ground in a Danish ball mill. We took the Danish formula and we mix two pounds of ultramarine blue to every 100 lb. of green, and taking that mixture, and mixing five pounds to the 94-lb. sack of cement in the ball mill, has given us a fairly deep green and one that seems to hold up wonderfully well. We have noticed no change of shade whatsoever in the roofs. We are using the Danish automatic machine and that sifts the color on the tile and then it goes under the troweling bars, and it is sprayed with a forked spray immediately after it goes through the first trowel bar, and then it is troweled again and cut. **Mr. Watkins.**

MR. MULLENCAMP.—I make the three colors, red, green and gray. We have had trouble with brown not getting one batch to look like another batch. A certain builder put on a brown roof and after that a number of brown roofs were put on. The first batch made a beautiful shade of brown and then it commenced to change. We bought it in fifty pound boxes, and it seemed to give us something different, especially in the special pieces—the pieces made by hand. We could not get the specials to look like a tile made in the machine. **Mr. Mullencamp.**

MR. BARNESKAN.—The tile made the first thing in the morning should be sprayed all over with the sprayer, all over the whole rack. Get the moisture to them as quick as you can. I find it a very important factor in getting a strong tile. It will help also to seal up the little holes that may possibly be on the top—the pin holes, fill them in before it is thoroughly set. Let the water lay on top and it will help to make it better—it does help to make stronger tile and to seal up the pores. **Mr. Barneskan.**

MR. IGGBERG.—Is it possible for a laboratory to set a standard on color—can it be done? **Mr. Iggberg.**

CHAIRMAN ALLEN.—I think it is done in the textile industry, and violet ray tests can be applied that will determine very quickly the non-fading qualities of any sample. **Mr. Allen.**

IRA H. WOOLSON.—Millions of square feet of roofing is placed on dwelling houses annually. There is admittedly a strong tendency in building conferences to urge and to get cities to endorse laws which will prohibit the use of combustible roofing. Each year we get more lessons on the necessity of non-combustible roofing. We have in the United States in the neighborhood of one hundred and twenty-five towns and cities which have forbidden the use of combustible roofing. Tile roofing has been very satisfactory in the past, and if you can make a tile at a price which will compete with the higher grades of metal roofing—which has come on the market within the last year, we can get that business. Cooper shingle roofing is being advertised in almost every technical and social paper and magazine in the country. If you can compete with that class of non-combustible material, you have an advantage because you have material which will not transmit heat like metal. There is a hazard in metal roof- **Mr. Woolson.**

Mr. Woolson. ing or in asphalted shingles which must be faced. A good sized fire-brand dropping on shingle or copper is very likely to start a fire. If you are able to compete so far as prices are concerned, then the sooner you get the product that will have a satisfactory and permanent color, the better it will be for your business, for just as soon as the public find out they can buy tile at a reasonable price, you will have the market.

Separate Group Meeting on Measurement of and Estimating Concrete for Contractors and Engineers.

Chairman Leslie H. Allen.—This group meeting has been called because a good deal of interest has been expressed by contractors lately in methods of measurement. Some ten years ago, a committee was appointed by the Institute to draw up methods of measurement of concrete work, the final report of that committee being adopted in 1913. A discussion of methods of measurement only is inconclusive, because it is so closely wrapped up with the question of how to estimate the cost when the work is measured, and, estimating costs leads into the further subject of how to keep track of the costs, in order to use them in estimates. And, so, it was decided to call this meeting of contractors and engineers and others who are interested in this subject, in order to discuss this whole subject informally, and see whether it was advisable to have a committee work on this subject during the year and report to the next convention for the guidance of contractors and engineers generally. As far as bidding on lump sum work is concerned, every contractor can be a law unto himself, if he desires. But in unit price contracts, if the architect draws up his units of mearusement in one way, and you are accustomed to figuring in another, trouble, difficulty and dispute soon arise; it must be very much in the interest of all, if we can get the engineers, the architects, and the contractors all thinking alike on the subject of measuring, and on the subject of cost estimating and cost keeping too. If one contractor tells an engineer that his concrete costs him $8.00 a yard, and on the engineer's next job a dispute arises, and the next contractor says his concrete costs him $17.00 a yard, both statements may be true for the same kind of concrete, if one man is talking of concrete alone and the other of concrete as including forms, finish, reinforcement, etc. It would be well to start the discussion by talking a little on how we should measure our work, and how we should estimate it, and how we should keep track of the costs. We have Mr. Ginder from the Treasury Department in Washington to open this discussion with a short talk on methods of measurement. Mr. Allen.

[Mr. Ginder's paper is printed on p. 162 of this volume.]

Mr. Allen.—Mr. Ginder's conclusions seem to run along very different lines from the conclusion of the original committee appointed nine years ago. First of all, he has stated that he is in favor of two methods of measurement, one for the contractor in his own work, and one for the engineer in settling unit price contract. There may be some room for a difference of opinion on that. Mr. Allen.

N. M. Loney.—The two things are so completely different, that they cannot even be discussed together, and it is really necessary to take into consideration so many additional elements for cost keeping that I don't see how the two can be taken together or discussed together at all. Then, Mr. Loney.

Mr. Loney. too, if this meeting is for the purpose of studying up standards which we shall recommend to engineers in the preparation of their specifications for concrete work, many different subjects will certainly come up, calling for entirely different treatment than if the meeting is for the purpose of determining the proper method of cost keeping. There are many things that need to be taken into account for cost keeping, that do not need to be taken into account for measurement for purposes of estimating. For instance, if we are going to attempt to convince all the engineers who write unit price contracts that they should measure and pay for forms separately, I believe we are undertaking a hopeless task, because then the unit prices will become involved. The best we can do is to separate concrete work into classes, perhaps in some general, rough relation to the kind of forms required.

Mr. Allen MR. ALLEN.—Where a contractor has a job on a unit price basis, and the contractor has given a per yard price on the concrete work including forms, if the plans, we will say, call for concrete walls twelve inches thick, then later on it is decided to make them eight inches thick, he losse heavily on that part of the work, whereas, if the thickness of the wall is increased, the owner pays for more form work than he gets.

Mr. Loney. MR. LONEY.—These two things cannot be discussed together, because they are so very different. One of the first things to do, in establishing a new method of paying by unit prices, is to think about how the engineer and the architect are going to take to that suggestion. The engineer is not likely to accept our rules; we can suggest a lot of standards for them, but I really don't think we ought to try to discuss at the same meeting the method of cost keeping, lump sum contracts and unit prices, because the two things are totally different.

Mr. Nichols. C. E. NICHOLS.—I don't agree with Mr. Loney that the things are so totally different that they cannot be discussed together. I think they have got to be considered together in this way: while the engineer and the architect will perhaps never be brought around to the stage of splitting up the unit price contract in as much detail as we have to do in estimating and keeping costs, at the same time, no matter how he draws his contract, or sends out his invitations to bid, no matter how he defines the units that he is going to make payments on, you have got to make your estimate and base the units in his contract upon a detailed check of it, as you would have to do in any lump sum contract. The only way you can safeguard either the owner or the contractor, on a unit price contract, is to define the scope of the units as set forth in the contract, and just how much you do split it up for a unit price contract, will depend on the number of different classes of work involved. We can educate the engineers and architects to a very large extent, but the only way we can do it is by bringing out and educating them to the real things which do affect the elements which must be considered in the cost, and for that reason, I think they have got to be considered together. I think they have got to be put before the public in the same group. I think it

would be well for the committee that may develop out of this thing, in writing any report, or setting forth any conclusions, to treat the two together, and while they perhaps will define different units to be used for making payments in unit price contracts, it must be stated what those units include in the way of details. I do think we can get into the subject of cost accounting and detailed estimating and quantity service for estimating and make some attempt to coordinate those with some recommended system of units for making payments on unit price contracts. And, I think we will stand a better chance of having those subjects coordinated properly if they are treated together, than if they are treated entirely separate. Mr. Nichols.

MR. JENRICK.—I believe in some cases you must consider the two subjects separately. Take, for example, the question of reinforcement. When you make your estimate, you should undoubtedly make your estimate including waste, but when you come in on the unit contract basis for reinforcements, how would you consider that waste? It would be difficult to get your engineers and contractor to agree on that. In making an estimate, I believe we should take care of waste, but in a unit price contract, the unit price should include the waste, and the actual reinforcement needed should only be considered. Mr. Jenrick.

H. W. HANLEY.—I believe it would be well for us to establish the purpose of the meeting, either to decide that we are to set up a set of standards which will be the basis for use in cost keeping, and for the educating of specification writers in writing unit cost contracts, or to divide the work of the committee, or of the meeting, into two heads, so that the purpose of the meeting will be the establishing of a set of standards which will be the basis for use, and for educational purposes, as Mr. Nichols has suggested. I would suggest that we operate along that latter line, of establishing, if we can, a set of standards for measurements, for the use of the contractor first, and then by education of the engineer and the architect finally. They are interlocking; one must depend upon the other, and I believe that the architect and the engineer must come finally to the contractor for his education in determining the division of his work, and it is up to the American Concrete Institute through this committee to establish those standards which can be the basis for all of those operations. Mr. Hanley.

(Here was read the paper by Frank R. Walker, printed on p. 156 of this volume.)

MR. ALLEN.—On the use of forms there is a good deal of difference of opinion. Take for example the stairs. Mr. Walker would take stairs through the entire building and estimate all the square feet of forms and of concrete, reinforcement and finish. Mr. Ginder's method is the lineal foot of stairs or number of treads, if all alike for width, but in order to get at the unit cost of them he would use the same method as Mr. Walker, so the two would lead to practically the same result. The care with which you subdivide the item of stairs, depends largely on the Mr. Allen.

Mr. Allen. relative importance of the stairs in the building. In the theater, where a good many thousand dollars is spent in constructing stairs, it is much more important to figure stairs accurately than in the factory, where a small amount of stairway is used. The method of figuring the lineal foot only, that Mr. Ginder speaks of, might cover factory construction, but in large and difficult jobs of stair work it might lead you far astray. Just what general rules we should lay down it is a little difficult to say, but probably the best thing is to cover the fundamental principles, going more into detail than would be used in the ordinary way by contractors on average work.

Mr. Gould. H. J. GOULD.—Is it necessary to take all the lumber in formwork in order to set up the unit? Why go to the trouble of taking off all the lumber?

Mr. Walker. FRANK R. WALKER.—I usually lay out one floor on a job and figure lumber in that which gives me a close average. I base my material price on that. Of course, in different types of floors you get variation in amount of lumber required. The amount of form lumber is made a matter of price, which I believe is the easiest way—we take off the total square feet of form work, making no effort to determine the amount of lumber that is going to be required, but we do take into account the various thickness of floors or various types of designs entirely as a matter of price.

Mr. Gould. MR. GOULD.—In taking off the square feet of forms and applying a variable price to it, your price is worked out from the amount of lumber required to the square foot. Although your cost may not recognize it, that is actually what the cost is determined by, the number of times you use the forms and practically the number of feet required for using.

Mr. Allen. MR. ALLEN.—The methods are essentially the same, you simply put in different units and receive practically the same result.

In the hurry and rush of getting out an estimate, is it possible to get an accurate estimate of lumber for forms (which is not shown on the plans)?

Mr. Walker. MR. WALKER.—I do not think it is, but I have worked out a little table that I use and I use that just as a basis. I never lay a new job out but I worked out those tables and have them on different jobs of floors and my price is always based on that. I can prepare a more accurate estimate by working on that basis than I can by just taking a similar job. You do not always have a similar job.

Mr. Nichols. MR. NICHOLS.—I think a contractor would finally establish rules of that kind, using tables of material that would be necessary to make forms for various types of floors, selecting one as similar as possible to the one where he would have determined his original cost by use of the principle obtained from the amount of material required.

Mr. Dingman. CHARLES E. DINGMAN.—In cases where the forms are designed by the engineer, the measurement might just as well be by the foot board measure as by square feet surface contact, since the contractor must estimate it on the basis of board measure.

MR. ALLEN.—That does not occur in building work. It does sometimes occur in bridge work and structures of that kind. Most of our discussion so far has been on building construction, although it hasn't been specifically mentioned here. Mr. Dingman makes the suggestion that if the engineer comes in and tells the contractor what form material he should use then the estimate should be made on that basis. **Mr. Allen.**

MR. WALKER.—In keeping costs, I ordinarily take the square feet of slab forms—if 60,000 ft. of forms, I multiply that by three or whatever is my average number of feet of lumber per square foot. Take 100,000 ft. of lumber say in the construction of forms, then I will divide the number of carpenter hours worked on that job and arrive at the number of hours required per thousand feet of lumber per measure and per 100 sq. ft. of forms, and in that way the variation in the scale does not make any particular difference. I believe that gives a very good comparison between your square feet and thousand feet price on the different types of floors. I work common labor hours on the same basis. Every day the hours are distributed, and we make three computations and estimate so much for the carpenters and so much for helpers and labor. For instance, if three feet of lumber are required to a square foot of forms, you get 333 forms to a thousand feet of lumber and then I have worked out the hours of the various trades required to erect and remove after the completion and use those units in arriving at the new price. **Mr. Walker.**

MR. JENRICK.—It is very difficult to have a time-keeper on the job to separate those hours and pro-rate time according to the classification on form work or whatever they may have to do. I have made a series of analyses on several jobs and I have found it will vary from four hours on carpenters to fifteen minutes, depending entirely on the job, but there again we have the relation not only of the carpenters to forms, but again splitting up the form in that some jobs have considerably more beam work, thereby making more hours of carpenter time, more in fact than on added board foot measure if the beam work adds to square foot of forms. **Mr. Jenrick.**

MR. GOULD.—From a cost standpoint there are two chief factors, which must be taken into account—the total labor and the quantity. The total labor is a matter which we only gather in dollars and cents in our company, although at specified times we will take a particular job and determine the ratio of mechanics and laborers. At one time we made that determination on forms, and determined 80% of the money cost was mechanics and 20% labor. From that we get at in some degree what Mr. Walker brings out in his hours of each craft. **Mr. Gould.**

Unless both the quantity measurement and the total labor is scheduled properly, naturally the unit cost is not accurate. So I feel a revision of these methods of measurements should be taken up by the Institute and made a little more definite. From a cost standpoint it is not wise to make too minute a division or too inclusive a devision for recording purposes. This is especially true of the method suggested for stairs. The

Mr. Gould. method suggested can not be costed. On that account we have come to take off linear feet of stair nosing only—for ordinary work that is satisfactory. Perhaps in theater, court house and work of that kind, more refined methods should be used, but linear feet of nosing is sufficiently accurate to take into account both the concrete, forms and steel. Very few contractors have time to take off the actual amount of concrete in a flight of stairs. That is one of the last things that is taken off, and the stairs are not a large enough item in the job to warrant the extra time. The time a contractor has to spend on an estimate could be better spent in refining the larger quantities, which more largely determine the price he is to receive. On forms the estimator should take account of beams, columns, column heads, etc., but the actual costing of that work is hard. To get the exact point where a column ceases and the beams or floor slab begins in actual construction work, is not the easiest thing for the man who records the costs, and I doubt if anybody who is attempting to record the costs that fine is getting it. The results in general do not warrarnt the time that it takes to get them. We do it on seventy-five per cent of our work, but when we are breaking in a new cost man, we always eliminate that as one of the frills, which can be eliminated without eliminating efficiency. As a timekeeper becomes more experienced on the job we make these comparisons.

In taking off quantities for an estimate on floor formwork the easiest way would be to take only the bottom and sides of the beam. We take off the entire floor area on the building, which would include the beam bottoms and then take off the sides. The cost of an octagonal or round column form is very largely determined by the size of the column. I do not see the value of taking off the quantity of bent steel. In general the estimate on that quantity will not be close enough to warrant the time required to take it off. We make no distinction in our costs as to the cost of bent steel and straight steel; for, in general, in building work a fairly constant proportion is bent. Very careful mention should be made of the surface treatment required, although it varies more with the inspection by the architect than by specifications. From a cost standpoint, cement finish of various thickness is not a very vital factor, and it does not make much difference in the labor cost whether cement finish is one-half inch thick or three-quarters of an inch thick. Practically the only difference is the additional material. In general I think that it is not wise for the quantity survey to be very far from what can be secured in costing, but I do not believe that it is fair to the cost department to ask them to keep the cost as fine as you can estimate it.

Mr. Allen. MR. ALLEN.—Mr. Gould makes a good point—that there is no use in measuring estimates of items, which the cost man cannot record and making measurements more elaborate than what is practical when keeping cost on the job. It is difficult to separate the cost of cutting and bending steel from the cost of cutting straight steel, and on stairs it is especially complicated. It is an elaborate job for a timekeeper to keep track of the

little items that enter into the cost of forming and placing concrete in stairs. If he cannot get it accurately, which is almost impossible, he has to guess at it and that is just where the cost keeping has a vital relation to the whole method of measurement. **Mr. Allen.**

MR. JENRICK.—I have always found that an estimator will go into a great deal more detail that he will ever secure cost records for. It is necessary to do so in order to get an accurate estimate, but we have not asked our cost man to go into these same details except where we find our estimate or unit cost of the item seriously differs from the cash cost on the job. In cases of that kind we have gone into detail and had a special analysis made of the items. In the making of measurements we should guide our estimator to that extent, that is, not throw away all that detail work. He should still go into it even though he is not getting the cost record for it, and in estimating these items of which he has no accurate account, he must depend on his judgment. **Mr. Jenrick.**

MR. ALLEN.—In figuring the cost of steel, if your cost man on the job is only computing total labor cost, and your estimator separates the bent steel and column steel from the floor steel and he uses his "judgment" in pricing the items even though he has no record to guide him, I do not see how that would be good practice. It would only be spending a lot of time getting quantities without any definite data to determine what would be the difference in the cost of the two. **Mr. Allen.**

MR. GOULD.—Steel fabricators want that detailed information and want to know the extra size and also bending in particular to the classification and the job all done, except for spiral stirrups or ties, but they do want the classification for bending and sizes. **Mr. Gould.**

MR. ALLEN.—The contractor must pay for what he gets, and even if he hasn't time to make his estimate in detail before he comes to purchase his steel, he has got to get it all sorted out and so far as paying for it is concerned (going back to the unit price of the contract we were talking about), is it fair to demand of consulting engineers that they should figure separately the amount above and below base and the quantity of bent steel and so on? That might make quite a difference on a job where all the floor slab steel is half-inch rods, six inches on center, if the engineer after letting the contract decided he would rather have three-eighths bars spaced more closely together. If there were no distinction made in quantities on that, the contractor would lose the differential cost. Suppose a contract contained only one unit price for all steel reinforcement. Suppose the original plans showed a large proportion of the tonnage in half-inch bars and in detailing that had been changed to three-eighths inch steel with closer spacing, the tonnage would be the same, but the cost of steel and labor to the contractor would be considerably more. One object in any system of measurement is to teach the consulting engineer what is fair and what is the right way to divide his quantities. If we have some Institute recommendations that remove these gambling elements from a contract we can ask consulting engineers to recognize them. **Mr. Allen.**

Mr. Allen. The question is how many refinements can we afford to put in.

Mr. Walker. MR. WALKER.—We can never get to the point of writing specific unit price contracts, to cover every possible change which may come up. But we can definie certain units of value which shall be used for any specific contract and at the same time state what detailed refinements do affect the costs and how they should be considered in making any change of prices due to any change in the work. If we get that far, we will have gone as far as we need go to protect contractor and owner, and whether they bring up and make any change depends upon the carefulness with which the contractor and the engineer follow the job and follow the changes which are made. We will never succeed in getting the engineer or architect to write into a price schedule for a given piece of work all the detailed items which affect the cost of any one part, or the contract would be too cumbersome. But we can set forth certain standards which recognize the unit prices. I think that would be a proper function of any committee attempting to formulate any rules. We should state how far such divisions ought to go, where to draw the line and why.

Mr Allen. MR. ALLEN.—The purpose of this meeting was to see how much interest there was in this subject and determine whether it would be well for the Institute to appoint a committee to reconsider this whole subject and draw up a report with revised rules. If we find it would be well to have such a committee we should present a resolution to the Institute asking that such committee be appointed.

Mr. Walker. MR. WALKER.—I move it is the sense of this meeting that the Institute should request the Board of Direction to appoint a committee to draw up and present to the Institute, rules or recommended practice for both measurement for concrete work as well as for use in estimating cost keeping or for determining payments in unit price contracts or similar instances.

This motion was duly seconded and put to the meeting and carried. The meeting was then adjourned.

RESOLVED that it is the sense of this meeting that the rules of measurement adopted by the American Concrete Institute in 1913 should be revised and amended, and that the Institute request the Board of Direction to appoint a committee to revise and amend these rules, having particular reference to the relation of cost estimating and cost accounting to the subject, this committee to be instructed to report at the next convention a revised set of rules of measurements, with reasons therefor.

Committee Reports American Concrete Institute, 19th Annual Meeting, 1923

REGULATIONS GOVERNING THE FORM BUT NOT THE SUBSTANCE OF STANDARDS.*

Application. 1. *APPLICATION*—These regulations shall be retroactive with respect to all existing standards. Standing Committees shall make an earnest effort to comply with them. Departures therefrom shall not be made by Standing Committees except on what they believe to be strong grounds, and then only after consultation with the Committee on Form of Standards. In case of a disagreement with the Committee on the form of standards, the matter shall be referred to the Advisory Committee, whose decision shall be accepted.

2. *ARRANGEMENT OF MATERIAL.*—The arrangement of material and the designation of sub-titles, etc., shall conform in general to the following:

I. GENERAL. (Sub-title.)

$\left.\begin{array}{l}(A)\\(B)\\(C)\end{array}\right\}$ (Principal sections under sub-title.)

(*a*), (*b*), (*c*), (*d*), etc. (Sub-divisions of a section. Lettering to run consecutively throughout one section only.)

II. MATERIALS.

(*A*)

(*B*)

etc.

III. DESIGN.

IV. DIMENSIONS, WEIGHTS, ETC.

V. CONSTRUCTION AND MANUFACTURE.

VI. WORKMANSHIP.

VII. SPECIAL REQUIREMENTS.

VIII. PACKING, MARKING AND SHIPPING.

IX. INSPECTION AND TESTS.

Sub-titles that do not apply to any given standard may be omitted.

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* These regulations, drawn up by American Concrete Institute Committee G-3 on Form of Standards, conform in general to those already adopted by the American Society for Testing Materials. They have been approved by the Board of Direction of the Institute as a means of attaining uniformity in Institute Standards in respect to form only and are thus issued for the guidance of Institute Committees.

Numbering Paragraphs.

3. *NUMBERING PARAGRAPHS.*—Individual paragraphs in each standard shall be numbered consecutively, irrespective of sub-divisions under which they appear.

Marginal Headings.

4. *MARGINAL HEADINGS.*—Some descriptive word or heading should be placed in the margin opposite each numbered paragraph, briefly indicative of the subject matter.

Units of Measurement.

5. *UNITS OF MEASUREMENT.*—Weights and measures shall be expressed in the English System. Temperature shall be expressed in degrees Fahrenheit.

Abbreviations.

6. *ABBREVIATIONS*—When abbreviations are used they shall conform to the following:

The policy should be to abbreviate too little rather than too much. Terms which seldom occur should in general not be abbreviated.

(*a*) *Units of Length.*

Foot	ft.
Inch	in.
Linear	lin.
Meter	spell out
Mile	spell out
Yard	yd.

(*b*) *Units of Area.*

Square	sq.
Square foot	sq. ft.
Square inch	sq. in.

(*c*) *Units of Volume.*

Barrel	bbl.
Bushel	bu.
Cubic	cu.
Gallon	gal.

(*d*) *Units of Weight.*

Ounce	oz.
Pound	lb.
Ton	spell out

(*e*) *Units of Time.*

Afternoon	p. m.
Day	spell out
Forenoon	a. m.
Hour	hr.
Minute	min.
Month	spell out

(*e*) *Units of Time.*

Second	sec.
Week	spell out
Year	spell out

(*f*) *Units of heat.*

Degree	°
Fahrenheit	F.

(*g*) *Miscellaneous Technical Terms.*

Birmingham wire gage	B. w. g.
Browne & Sharpe (gage)	B. & S.
Chemically pure	c. p.
Degree (angular measure)	deg.
Diameter	spell out
Revolutions per minute	r. p. m.
Specific gravity	sp. gr.
Tensile strength	tens. str.
United States (gage)	U. S.

(*h*) *Miscellaneous General Terms.*

Figure	Fig.
Number	No.
Per	spell out
Per centum	per cent
Proceedings	Pro.
Plate	spell out
Table	spell out
Transactions	Trans.
Volume	Vol.

Abbreviations.

(*i*) Use abbreviations only after nouns denoting a definite quantity, except in tabular work. For example: "The tensile strength is 45,000 *lb. per sq. in.*"; but "The tensile strength in *pounds per square inch is* ......"

(*j*) When terms are used in an abstract or descriptive sense, they shall not be abbreviated. "The work should be done in the *forenoon*", not "in the *a.m.*"

(*k*) Use a period after each abbreviation, except after *per cent*, and as noted in sub-division (*m*).

(*l*) All abbreviations shall be used in the singular. Thus, "two inches" shall be abbreviated "2 in."; not "2 ins."

(*m*) *Compound Words.*—The abbreviations for compound words, when used, shall be formed by connecting the abbreviations of the separate words of a hyphen, and omitting the period preceding the hyphen. Thus, "ft-lb., in-lb."

(*n*) *Symbols.*—Avoid the use of symbols. Do not use (′) or (″) in either text or tables; their use is permissible in illustrations. The symbol (%) shall not be used in the text, but may be used in tables when lack of space requires it.

(*o*) The word "percentage" shall be used when not following a number. Thus, "the *percentage* of reinforcement shall be"; not "the *per cent* of reinforcement shall be." But, "0.77 *per cent* of reinforcement."

(*p*) In expressions like the following, omit the degree mark after the first figure: "75 to 80° F." In a table heading, use "Temperature, *deg. Fahr.*"

(*q*) In expressing dimensions, use the following form: "2 by 4 in. in section;" not "2 x 4 in. in section," nor "2 in. by 4 in. in section."

(*r*) Spell out the names of the months: as, "January 25." Do not use the form "January 25th."

(*s*) In text, do not abbreviate "namely" and "that is".

(*t*) Spell out names of companies, railroads, etc., using the ampersand (&) only between proper names. Abbreviate "Company" in firm names. For example: "Brown & Sharpe Manufacturing Co.," "Philadelphia & Reading Railway Co."; but, "American Steel *and* Wire Co."

Numerals.

7. *NUMERALS.*

(*a*) Roman numerals should be used in designating tables and plates: thus, "Table VI"; not "Table 6." Arabic numerals should be used in designating figures: thus, "Fig. 3"; not "Fig. III."

(*b*) Spell out all numbers from one to twelve, with the following exceptions: Numerals

1. Use numerals when the quantity is partly or wholly fractional: as, 1.15, $1\frac{1}{2}$, $\frac{1}{3}$.

2. Use numerals when followed by an expression having a standard abbreviation: as, 1 in., 6 lb., etc.; except where the statement is vague in nature, in which case neither numerals nor abbreviations shall be used: as "about *six pounds*, etc.

3. If for any reason the standard abbreviation of the expression following the number is not used, or, if the expression does not admit of abbreviation (as mile, ton, etc.) the use of numerals shall be optional, unless covered in the following paragraphs.

4. In contrasted statements, if some numbers must be numerals, use numerals for all, as "2 miles and 16 miles."

5. In a series of connected numerical statements implying precision, use numerals: as, "2 years, 5 months, 3 days." The use of numerals (especially the "1") is not recommended for numbers occurring in precise statements similar to the following: "By connecting the *two* columns", "shall consist of *two* bars."

6. Use numerals after abbreviations, as, Vol. 6, Fig. 2, etc.

(*c*) Use numerals for all numbers exceeding twelve, with the following exceptions:

1. Do not begin a sentence with a numeral.

2. Round numbers used in an indefinite sense shall be spelled out; as, "A *hundred* feet or so," etc.

3. Numbers shall be spelled out when used in the following manner: "*fifteen* 1-in. rods," etc.

(*d*) In decimal numbers having no units, a cipher shall be placed before the decimal point: as, "0.65 in."; not ".65 in."

(*e*) In expressing percentages, precise figures, etc., use decimals: as, "4.5 per cent"; not "4½ per cent."

(*f*) Omit unnecessary ciphers in sums of money, as, "$3"; not "$3.00."

(*g*) In pointing off numbers of more than four figures, use commas in the text (1,234,567) and spaces in tabular matter (1 234 567). Numbers of four figures shall not be pointed off in either text or tabular matter (1234), except when they occur in a table containing any number of more than four figures.

(*h*) Always use numerals for the day of the month when the month is given (January 25, 1913) and for the time of day (2.30 p. m.).

Spelling and Punctuation.

8. *SPELLING AND PUNCTUATION.*

(*a*) *Simple Words.*—The following spelling shall be used:

aging	formulas	paraffin
briquette	fulfil	program
cent*er*	gage	re*i*nforced
crystallin	gasol*i*ne	skil*l*ful
dis*k*	*i*nsure	sul*f*ur
*e*mbed	mold	turpentine
fib*er*	oxid*e*	

(*b*) *Compound Words.*—The following spelling shall be used:

Spell with hyphen.

cold-rolled	one-half
cross-section	open-hearth

Spell without hyphen when used as noun.

cast iron	testing machine
plaster of Paris	wrought iron

Spell as one word.

cooperate	quicklime
eyebar	reroll
fireproof	retest
footnote	reweigh

(*c*) Compound adjectives shall be hyphenated; as, "2-in. gage," "cast-iron cylinder." Such expressions as the following shall be written *without* the hyphen after the first numeral: "2 and 6-in. specimens."

Capitals.

9. *CAPITALS.*

(*a*) Use capitals sparingly.

(*b*) Capitalize the principal words in headings, titles of books, papers, etc. (nouns, verbs, adjectives and adverbs).

(*c*) Use capital initial "C" for "committee" when used as a title: thus, "Committee on Organization," "Committee on Papers." In all other cases use lower-case "c"; thus, "The committee recommends ......"

(*d*) Use capital initial "B" for Bessemer; lower-case "p" for portland.

(*e*) Use initial capitals in reference to volumes, figures, plates, etc.: as, Vol. 6, Fig. 2, Plate VI, Table III.

(*f*) Use the form "test No. 1," "specimen A," etc.

10. *STANDARD TERMS AND FORMS OF EXPRESSION.*

Standard Terms and Forms of Expression.

(*a*) Use "shall" wherever the standards are to be made binding on parties of the first or second part.

(*b*) Use "will" wherever the standards are intended to express a declaration of purpose not mandatory upon the parties of the first or second part.

(*c*) Use "may" wherever the standards provide definitely for alternative courses.

(*d*) Use "full-size tests"; not "full-size*d* tests," etc.

(*e*) Use "gage length"; not "gage*d* length."

(*f*) Use "test *specimen*" not "test *piece*." In case the term "test specimen" is repeated several times in the same section, the word "specimen" may be used after the first use of "test specimen."

(*g*) Use "$\frac{3}{8}$ in. *or* over in thickness"; not "$\frac{3}{8}$ in. *and* over."

(*h*) In referring to dimensions, use simply "2 in."; not "two inches (2 in.)," or "two (2) inches."

(*i*) Use the form "without *cracking*" in referring to bend tests of metals; not "without *sign of cracking*."

(*j*) Use "reduction of area"; not "reduction *in* area" or "*contraction* in area."

11. *FOOTNOTES.*

Footnotes.

(*a*) Use superior figures instead of asterisks, etc., except in connection with numerals, for which use letters.

(*b*) The names of journals, proceedings, bulletins, etc., shall be printed in italics, without quotation marks; the titles of papers and reports should be printed in Roman and enclosed in quotation marks.

(*c*) Abbreviate the names of societies.

(*d*) When reference is made to a paper or report by title, only the initial page should appear in the footnote. Thus:

....(Name of Author)...., "....(Title of Paper)....," *Proceedings*, Am. Conc. Inst., Vol. XVI, p. 283 (1920).

When such titles are not given, or when reference is made to certain parts of papers, reports, etc., page numbers should be indicated, as follows:

Engineering News-Record, March 10, 1921, pp. 412–414.

(*e*) When volume numbers are given, the year of publication shall appear in parentheses at the end of the footnote. Otherwise, the date of publication should appear immediately after the name of publication. (See above examples.)

Report of Committee J-2, Joint Concrete Culvert Pipe Committee.

Since the last report of this committee at the annual meeting in February, 1922, the Joint Committee has held three meetings—April 7, 1922, at Chicago; June 28, 1922, at Atlantic City, and Jan. 20, 1923, at Chicago, all of which were well attended. The tests referred to in the previous report have been continued and much valuable data secured. The object of these tests was to secure information covering loads on culverts in railroad and highway embankments and if possible to discover the laws of variation of such loads. Although these tests are not yet concluded we have in general found certain underlying principles to be involved.

The ability of a culvert pipe to carry a load after it has been built into a culvert depends on construction conditions as well as upon the strength of the pipe itself. The construction conditions referred to may be summarized briefly as follows:

1. *Ditch Conditions*, are those where the pipes are laid in a ditch in the same manner as used for sewer pipe. The same rules for proper bedding apply for culvert pipe as for sewer pipe. If the pipe is laid directly on the flat bottom of the trench without special care to make bedding fit the pipe, the supporting strength of the pipe is not more than 80 percent of the strength where the bottom of the ditch is rounded to fit the pipe for 60 deg. to 90 deg. of the lower circumference. If the pipe is thoroughly bedded on soil carefully shaped to fit the pipe for at least 90 deg. of the lower circumference and the entire pipe is surrounded with well tamped soil, the supporting strength of the pipe is still further increased by at least 20 percent. If the culvert pipe is laid in a ditch that has been excavated in the original soil or in a partially laid embankment, the ditch back filled with loose material and then the balance of the embankment completed the load on the pipe approximates that for full "Ditch Conditions," provided the depth of the ditch is something less than one-third the total height of the finished embankment. The actual vertical load on the pipe laid under "Ditch Conditions" is less than the weight of the earth directly over the culvert.

2. *Imperfect Conditions*, is where the embankment extends to a total height greater than three times the depth of the ditch referred to under "Ditch Conditions." The load on the culvert pipe is greater than produced by "Ditch Conditions" but is less than that produced by "Projection Conditions." In the tests made at the Iowa Engineering Experiment Station the total maximum load for a 20 ft. fill was reduced 33⅓ percent.

3. *Projection Conditions* is where the pipe projects above the surrounding soil. The load on the pipe will vary depending on the amount of this projection but appears to always be more than the weight of

the material directly over the culvert. The experiments so far conducted indicate this load may be as much as twice the weight of the material above the pipe. The entire Joint Committee feel there must be some compensating horizontal pressures as well as other possible conditions that tend to reduce the stresses in the pipe, otherwise the large amount of culvert pipe now doing satisfactory service could not have withstood the heavy vertical loads indicated by the tests so far conducted. It is planned to make tests to determine these conditions as well as to continue the tests for vertical loads. These will include further experiments for superimposed loads, impacts, strength tests of pipe and a study of the behavior of culverts in actual use. At the last meeting of the Joint Committee it was decided to revise the pipe classifications referred to in your committee's report of last February. This change seemed advisable on account of certain misunderstandings of some engineers using these classifications. The revised tentative classifications are as follows:

> 1600 D pounds per lineal foot of pipe where "D" is the nominal internal diameter of the pipe, using the three point bearing test as described in American Society for Testing Materials Standards, Serial C 14-20. Pipe for this class must sustain a load of 1600 D pounds per lineal foot at the appearance of the first crack and the ultimate strength of the pipe must be at least 50 percent more.
>
> 1300 D pounds per lineal foot of pipe. Pipe for this class must sustain a load of 1300 D pounds per lineal foot at the appearance of the first crack and the ultimate strength of the pipe must be at least 50 percent more.
>
> 1000 D pounds per lineal foot of pipe. Pipe for this class must sustain a load of 1000 D pounds per lineal foot at the appearance of the first crack and the ultimate strength of the pipe must be at least 50 percent more.

The first crack is defined as that visible to the eye and extending the full length of the pipe. Although the limitations of these classes are not yet determined it is suggested that pipe fulfilling the requirements of the 1000 D class be used for fills up to 12 ft., the 1300 D class for fills up to 16 ft., and the 1600 D class for fills up to 20 ft. The Joint Committee is of the opinion that the above limitations are decidedly on the side of safety and that much higher fills can be used if care is used in embedding the pipe and constructing the embankment. For the present it is recommended that a given pipe specimen be judged by performance rather than by theoretical design.

Your committee respectfully submits this as a progress report and recommends that the American Concrete Institute continues to be represented on the Joint Committee.

B. J. PEASE, *Chairman.*
A. B. COHEN.

Report of Committee E-7, on Waterproofing.

During the year your Committee E-7 has held two meetings of the general committee and a number of meetings have been held by the various sub-committees. At its first meeting the following resolutions were adopted:

1. That the committee take up the subject of waterproofing from the standpoint of performance of materials as determined by tests.
2. That the committee consider the method of application of the material to the structure, to be presented in the form of a specification.
3. That the committee consider the waterproofing details exclusive of structural design and present same in the form of a recommended practice.
4. That committee formulate recommended practice for producing watertight concrete without the use of integral compounds membranous or surface treatments.
5. That the committee consider and recommend general principles which might control types of waterproofings to be applied to particular jobs of construction, same to be presented in the form of a recommended practice.

The scope of work and the personnel of the sub-committees is as follows:

Sub-Committee 1.
Integral Methods and Plaster Coatings.
A. B. Cohen, *Chairman.*
A. W. Stephens
Duff A. Abrams
W. A. Freret
S. B. Newberry

Sub-Committee 2.
Penetrative Surface Applications.
E. H. Berger, *Chairman.*
A. E. Horn
M. O. Withey
J. C. Pearson

Sub-Committee 3.
Bituminous Coatings and Membranous Systems.
G. L. Lucas, *Chairman.*
Ernest Ashton
E. H. Berger

Chas. N. Forrest
M. Toch
S. R. Church

Sub-Committee 4.
Non-Bituminous Surface Coatings.
Hermann Fougner, *Chairman.*
Ernest Ashton
J. C. Pearson
A. E. Horn
J. H. Libberton

Sub-Committee 5.
Waterproof Concrete.
A. W. Stephens, *Chairman.*
Duff A. Abrams
H. Fougner.

SUB-COMMITTEE 1—INTEGRAL METHODS AND PLASTER COATINGS.

Sub-Committee 1 has prepared an outline of the work being undertaken by it which is as follows:

1. Inert Compounds—
   (a) *Natural compounds.*
   Diatomaceous, infusorial earths, volcanic ash, clay, calcium carbonate, etc.
   (b) *Prepared by mechanical means.*
   Ground materials such as silica, tufa, ground limestone, rocks, etc.
   (c) *Prepared by chemical processes.*
   Pulverized slag, hydrated lime, insoluble soaps, hydrocarbon emulsions.

2. Chemically Active Compounds—
   Calcium chloride, oxychlorides, ammonium stearate, ammonium resinate, alginates.

3. Plaster Coatings—
   (a) With inert compounds.
   (b) With chemically active compounds.
   (c) With no admixtures.

The Sub-Committee is to investigate all of the subjects above mentioned, compile all the available information and later request the cooperation of various laboratories for the purpose of checking and adding to the knowledge in this field. Specifications for integral waterproofing will be prepared based upon the information thus collected.

SUB-COMMITTEE 2—PENETRATIVE SURFACE APPLICATIONS.

The work of Sub-Committee 2 is limited to those products which penetrate into the surface of the concrete filling the pores and thus rendering the surface impervious to moisture. These compounds may be inert and owe their effectiveness to their pore or void filling properties, or they may react with constituents in the surface treated, forming compounds of greater volume, pore-filling capacity, and more insoluble in water. Compounds, the chief value of which depends upon their ability to form surface films, are not included.

Classification of Penetrative Surface Coatings.

1. Water solutions of inorganic salts which react with the lime hydrate or other constituents in the concrete.
   (a) Magnesium, zinc, lead and other fluosilicates.
   (b) Sodium silicate.
   (c) Zinc, iron and aluminum sulphates.
   (d) Barium and calcium chlorides.
   (e) Alum.

2. Water suspensions of substances or mixtures of substances of a pore-filling character of which react and form pore-filling compounds. Water suspensions of iron fillings and ammonium chloride are of this character.

3. Soaps.
   (a) Water solutions of alkali soaps which react with the free lime or lime hydrate forming insoluble soaps.
   (b) Solutions of alkaline earth or heavy metal soaps in solvent which are deposited in the pores on the evaporation of the solvent.

4. Combinations of solutions in two or more applications and which react in the pores of the concrete, filling them with substances of a water-repellent or insoluble character.
   (a) Soap solutions and inorganic salts.
   (b) Inorganic salt solutions.

5. Solutions of liquid and solid hydrocarbons—heavy petroleum distillates and paraffin dissolved in solvents which penetrate into the concrete surface and fill the pores with a water-repellent substance upon the evaporation of the solvent.

6. Waxes, fats and solid hydrocarbons, melted and driven into the pores by the application of heat.

The members of the Committee are now active in collecting all available data they have on the use of the above compounds and their value for waterproofing purposes.

SUB-COMMITTEE 3—BITUMINOUS COATINGS AND MEMBRANOUS SYSTEMS.

Although three meetings of Sub-Committee 3 have been held during the year and considerable progress has been made, its work has not advanced sufficiently to permit of the presentation of specific recommendations at this time.

To avoid duplication of the work of Committee D-8, A. S. T. M. on Methods of Test and specifications for waterproofing materials, the deliberations of Sub-Committee 3 this year have been confined to the classification of Bituminous Coatings and Membrane Systems and the application of these materials for damp-proofing and waterproofing various types of structures.

Sub-Committee 3 has kept in close touch with the work of D-8, A. S. T. M., by interlocking membership, and such substantial progress has been made in D-8 on Materials, that it will doubtless be unnecessary for Sub-Committee 3 to devote any of its time to this phase of the subject.

The scope of the specifications for application now receiving the consideration of this Sub-Committee includes the following subjects:

1. Damp-proofing, both above and below ground level, by means of bituminous coatings without membrane reinforcement, and which may be applied respectively in an unheated or heated condition as the circumstances may require according to the following outline—

   Damp-proofing—Bituminous surface coatings without reinforcement.

   (a) Cold application.
      (1) Cold application above ground level.
         a. Paint for stone backing to prevent staining of exposed surfaces.
         b. Damp-proof coating applied on the inside of exterior walls to prevent staining of plaster from water.
      (2) Cold application below ground level.
         a. Heavy bodied liquid cement.
         b. Fiber-filled liquid cement.
         c. Fiber-filled plastic cement.

   (b) Hot applications.
      (1) Hot application above ground level.
         Same as below ground level.
      (2) Hot application below ground level.
         a. Low melting bituminous cement.
         b. High melting bituminous cement.

2. Waterproofing, by means of hot bituminous coatings, reinforced with a membrane of either felt, or fabric or of both according to the following outline.

Membrane waterproofing.—Bituminous coatings with reinforcement. All hot applications.

(a) Exposed to atmospheric fluctuations of temperature.

1. Felted fabric } Reinforcement.
2. Woven fabric }
3. Low melting bituminous cement } Bituminous coating.
4. High melting bituminous cement }

(b) Exposed to uniform temperature.

1. Felted fabric } Reinforcement.
2. Woven fabric }
3. Low melting bituminous cement } Bituminous coating.
4. High melting bituminous cement }

(c) Water pressure exposure.

1. Felted fabric } Reinforcement.
2. Woven fabric }
3. Low melting bituminous cement } Bituminous coating.
4. High melting bituminous cement }

(d) Vibration exposure.

1. Felted fabric } Reinforcement.
2. Woven fabric }
3. Low melting bituminous cement } Bituminous coating.
4. High melting bituminous cement }

3. Waterproofing by means of bituminous mastic or bituminous grout, according to the following outline:
Mastic and Grout Waterproofing—Bituminous surface coatings consisting of a bituminous cement and a graded mineral filler.
(a) Floors.
(b) Reservoir and tank linings.
(c) Special, with brick or tile reinforcement.

SUB-COMMITTEE 4—NON-BITUMINOUS SURFACE COATINGS.

The scope of Sub-Committee 4 has been limited to those products which form surface films in counter distinction to those which have pore fillings, but not filming qualities.

Sub-Committee 4 is considering its work under the following subdivisions:

(a) Cellulose compounds.
(b) Drying and semi-drying oils.
(c) Admixtures with the drying and semi-drying oils of other materials for special qualities.
(d) Pigment admixtures with the above, generally called paints.
(e) Solid materials which require heating for application.
(f) Solid materials thrown into solution by solvents of various kinds.
(g) Metallizing processes.

All the available data on these sub-divisions is being assembled and will later be compiled and tabulated. Immediately thereafter it is the purpose to request the co-operation of various laboratories in further research work for the purpose of completing such data as may not now be available.

SUB-COMMITTEE 5—WATERPROOF CONCRETE.

The work of this committee is being limited to producing waterproof concrete by a combination of portland cement and water with fine and coarse aggregates.

Concrete in which there is a material other than portland cement and the materials ordinarily used as fine and coarse aggregates will not be included in the work of the committee.

The following outline is intended to cover the work of the committee:

Materials.

Portland Cement:

Effect of fineness.
Effect of time to set.
Effect of strength.
Effect of variation in quantity.
Effect of composition.

Sand and Fine Aggregate:—

Effect of excess of fine sand.
Effect of excess of coarse sand.
Effect of grading.
Effect of impurities.
Effect of composition of sand.
Effect of use of slag sand.

Coarse Aggregate:—

Effect of excess of small sizes.
Effect of large sizes.
Effect of grading.
Effect of coarse aggregate consisting of gravel.
Effect of coarse aggregate consisting of broken stone.
Effect of coarse aggregate consisting of slag.

Water:—

Effect of excess of water.
Effect of too small a quantity of water.
Effect of temperature of water.
Effect of impurities in water.

Proportioning of Materials:—

Effect of varying proportions.

Hand Mixing and Machine Mixing:—

Effect of order in which material is incorporated.
Effect of thoroughness of mixing.
Effect of temperature at the time of mixing.
Effect of nature of surface finish such as trowelling.
Effect of age upon waterproofness of concrete.
Effect of strains due to loading of member.
Effect of temperature changes on waterproofness.
Effect of shrinkage on waterproofness.
Effect of steel reinforcement upon waterproofness.

Curing:—

Effect of conditions during curing.
Protection.

Placing:—

Effect of method of placing concrete.
Laitance.
Effectiveness of thickness of concrete member.
Need for expansion joints.

The work of Committee E-7, as will be noted through the activities of the sub-committees, is at present that of collecting a mass of data relating to the comprehensive outline of the field. It will not be possible, until this work is completed, to prepare comprehensive specifications accurately based upon fact. It is hoped, however, that the work will be sufficiently advanced in some quarters to present well-considered specifications at the next convention.

J. H. LIBBERTON, *Secretary.*

Report of Committee E-6, on Destructive Agents and Protective Treatments.

CONCRETE IN SEA WATER

In approaching the study of the use of concrete in both fresh and sea water, your committee has deemed it wise to ascertain, as nearly as possible, the experience and practice of engineers who have had the greatest opportunity to give thought to this particular phase of concrete construction. A very careful review of the bibliography has been made and, in addition, a questionnaire has been sent out to about seventy-five of the leading railroad, harbor, government and municipal engineers who, in the committee's opinion, were most apt to have data on this important subject. A copy of this questionnaire is attached. (Fig. 1.) The compilation of this information, in our opinion, contributes sufficient data to warrant our careful consideration.

Of the fifty-one replies received to the questionnaire, all but one gave approval to the use of concrete in fresh or sea water, and they were practically unanimous in stating that experience led them to believe that the failures of concrete in sea water service were attributable to either improper materials or poor workmanship. The advice on how to choose the materials and mix, place and cure concrete is, in many instances, vague, but the sum total of the information seems to offer a substantial contribution to the art, and your committee therefore feels justified in reporting the facts.

The most emphasized essential of concrete for this service is impermeability, and, therefore, all methods of obtaining a mixture having this characteristic seem to have a place in any discussion pertaining to this subject. This, together with the best practices in the selection, proportioning, mixing, pouring, curing and protection of the exterior skin of concrete must all be considered.

For the purpose of this paper, it seems unwise to introduce the problems of the life of concrete in fresh water. Usually the permanency of concrete under the action of fresh water is unquestioned, but there are several districts in this country where serious disintegration has been encountered. These seem to be special cases, however, which may be treated in a later report of this committee.

As is generally known in the concrete world, the exact chemical actions which occur when concrete is exposed to sea water are, as yet, only conjectures on the part of the engineer. One school, which is followed

by the Bureau of Standards' exhaustive report on this subject* and generally approved by most chemists, believes that it is the action of the sulphate of magnesia of the sea water with the lime in the cement, (formed

FIG. 1.—QUESTIONNAIRE SENT OUT BY COMMITTEE ON CONCRETE IN SEA WATER.

1. Have you concrete structures under your observation subjected to the action of either sea or fresh water?
2. Do any of the structures show deterioration? If so, to what do you attribute it? Describe nature of deterioration. State age of structure and when deterioration began.
3. Was the exposed surface cast in place or precast and cured prior to being placed?
4. Is the water salt? What per cent?
5. Is the structure reinforced? If so, how far back from the surface is the reinforcement and what is the size?
6. What mixture of concrete was used?
7. Describe (a) sand; (b) gravel; (c) stone; (d) cement.
8. Attach concrete specifications if they are available.
9. Have you any special specification for cement? If so, please attach hereto.
10. If you were doing the work again, how would you change your specifications?
11. Have you ever used protection on the exterior of concrete such as (a) oils; (b) paint; (c) wood coating, etc.? With what effect?
12. Has there been any attempt to make concrete of maximum density?
13. Have aggregates been classified and graded?
14. Is the concrete exposed to ice or other abrasive flotsam?
15. What is your feeling about the use of concrete for sea water or fresh water construction?
16. Has your experience demonstrated any theory which holds in the making of concrete permanent? If so, state it.
17. Have you any reports or treatises on concrete used in salt or fresh water? If you have, please loan or send us copies.

during the setting) and the alumina of the aluminates of the cement, resulting in the formation of hydrated magnesia and calcium sulpho-aluminate, which crystallizes with a large number of molecules of water, and that both sodium chloride and magnesium chloride rapidly attack the silicates.

*Technologic Papers, Bureau of Standards, No. 12, by Messrs. Bates, Phillips and Wig.

This action is due to the greater affinity of sulphur for calcium so that when the cement and the sea water come together in the nascent state of chemical combination, the sulphur leaves the magnesium and combines with the calcium of the cement, forming calcium sulphate, and leaving the magnesium free. It is for this reason that magnesium is frequently observed on the exterior of concrete structures which are subjected to the action of sea water. For a time chemists were of the opinion that the magnesia in the cement was in some way responsible for the deterioration. It is the feeling of the chemists of the Southern Pacific Lines, who have made a very careful study of this, that magnesia in the normal amounts permitted in portland cement is probably inert and does not cause the cement, in time, to expand and crack. In the transition of the sulphate of magnesia to the sulphate of lime, the two equivalents of water comprise a considerable increase of volume. This formation in itself is sufficient to destroy the cohesion, but the aluminate of lime which exists in cement in common with other calcareous salts possesses the property of combining with the sulphate of lime and thus forming sulpho-aluminate of lime. This combination carries with it such a large quantity of water that it is necessarily increased in volume, which, in turn, totally destroys the cohesion.* Fortunately, the magnesium hydrate formed by the actions above described tends to counteract the destructive effect by filling the pores of the concrete so that in this way the material may gradually become impervious to the sea water and disintegration is thereby prevented. After the character of the cement has been changed by the formation of the sulphate aluminate of lime, the sodium chloride in the water is able to dissolve the calcium silicate in the cement. The calcium set at liberty is dissolved little by little in the water which penetrates the mortar and gradually reduces the concrete. The softening of concrete seems to take place only when there is an abnormal amount of sulphuric acid present.

Sea water has no apparent action on the iron oxides of cement. For that reason (and because of the fact that the setting quality of cement is due to the iron and alumina present, and, as indicated above, alumina is a harmful factor in sea water) it would seem that a cement high in iron is desirable. It is impossible, however, to replace all the alumina by iron, as a product resulting from the burning of ferric oxide and calcium carbonate does not possess hydraulic properties. To produce a cement that will resist the action of sea water, according to a theory embraced by a certain railroad,† deduct the percentage of iron from the percentage of alumina; the result should be not less than four.

Continuing with the tests of this same railroad, it is of great interest to observe that the subjecting of pats of neat cement to water having

*J. A. O'Hara, Chief Chemist of the Southern Pacific Railroad, states that in his experience it was found that over twice as much lime was extracted or set free when the cement set under the action of sea water as against the same condition in fresh water.

†Southern Pacific Lines.

slightly concentrated salts that are found in sea water showed total disintegration within ninety days, all apparently due to the foregoing chemical action. This test was confirmed by submitting some of the same cement pats to the action of real sea water over a period of one year. On the other hand, sand briquettes of 1: 3 mix, made for physical tests in the ordinary way, submerged in sea water, showed an increasing strength during tests that continued over a year. This may spell a caution in the minds of engineers in the matter of not proportioning their mortars in too great a percentage of cement. The inert sand seems to materially aid the cement in its resistance to the previously described chemical reactions.

There seems to be no disagreement among the engineers or chemists with respect to the permanency of concrete which is entirely submerged. It is that portion of the structure which is subjected to the alternate action of water and air in which the destructive action is most apparent. In reviewing the supposed chemical actions described, it is obvious that this crystallization should take place where the alternate action of water and air prevails. In this respect, the chemical hypothesis seems to be substantiated in general practice.*

From this discussion of the supposed chemical actions, it seems wise to turn to a practical definition of the problems which have been developed from the information gleaned through experience, the questionnaire and the practical experiments that have been carried on on this particular subject. For convenience and to avoid confusion, it seems wise to consider the subject under the following headings:

1. Impermeability and Density.
2. Proportioning and Mix.
3. Quantity of Water.
4. Forms, Spading and Tamping.
5. Curing.
6. Proper Location and Percentage of Steel.
7. Avoidance of Seepage or Drainage Action, Especially During the Period of Setting.
8. Avoid Placing the Concrete Where it is Subject to the Alternate Action of Air and Water During the Period of Setting.
9. Exterior Protection of Concrete.
10. Cement.

We are particularly fortunate in the contribution made by one of our leading construction companies† to this particular art. The tests which they carried on at the Charlestown Navy Yard, Boston, Mass., are perhaps the most scientific tests of long duration pertaining to the action of sea water on concrete which have ever been brought to the attention of the engineering world. The specimens, which have been exposed for more than

*See Technologic Paper, Bureau of Standards, No. 12, on the Action of Salts in Alkali Water and Sea Water on Cement, for recommendation on the best characteristic of cement for this particular service.

†The Aberthaw Construction Co., Boston, Mass.

FIG. 2.—1920 REPORT. ABERT

Pile No.	Concrete. Mix.	Concrete. Consistency.	Concrete. Wt. per cu. ft.	w/c Cement. cu. ft.	w/c Water. In Sand, lb.	w/c Water. Add, lb.	w/c Water. Total. lb.	w/c Water. Total. cu. ft.	w/c Ratio w/c	Water in Core Hole in 1909.	19
1	1:1:2	Dry	152.1	10.70	48	248	296	4.74	0.44	38	Slight
2	1:1:2	Plastic	151.1	11.33	48	295	343	5.49	0.48	65	O
3	1:1:2	Very wet	145.0	11.27	48	425	473	7.56	0.67	0	O
4	1:2½:4½	Dry	145.8	5.74	61	165	226	3.62	0.63	60	Slight
5	1:2½:4½	Plastic	150.3	5.55	61	195	256	4.10	0.74	52	O.
6	1:2½:4½	Very wet	152.2	5.73	61	345	406	6.50	1.13	0	Surfac
7	1:3:6	Dry	142.5	4.69	59	182	241	3.86	0.82	16	Slight
8	1:3:6	Plastic	146.6	4.68	59	240	299	4.80	1.03	22	O.
9	1:3:6	Very wet	145.4	4.68	59	343	402	6.43	1.35	0	O.
10	1:1:2	Wet	142.1	12.05	48	305	353	5.65	0.47	0	O.
11	1:3:6	Wet	146.2	4.80	59	353	412	6.60	1.38	0	O.
12	1:1:2	Wet	145.9	11.45	48	325	373	5.97	0.52	0	O.
13	1:3:6	Wet	142.8	4.62	59	345	404	6.46	1.40	0	O.
14	1:1:2	Wet	144.2	11.35	48	330	378	6.05	0.53	0	O
15	1:3:6	Wet	142.7	4.66	59	335	394	6.30	1.35	27	O
16	1:1:2	Wet	149.6	11.35	48	315	363	5.81	0.51	0	O.
17	1:3:6	Wet	145.9	4.67	59	293	352	5.63	1.20	0	O
18	1:1:2	Wet	145.6	11.45	48	330	378	6.05	0.53	0	O.
19	1:3:6	Wet	143.3	4.65	59	370	429	6.86	1.48	0	Slight
20	1:3:6	Plastic	145.5	4.62	59	275	334	5.35	1 16	0	Slight
22	1/10 Hydrated Lime 1:3:6	Wet	146.7	4.17	59	325	384	6.15	1.47	0	O
23	Sylvester 1:3:6	Wet	137.9	4.73	59	298	357	5.71	1.21	0	F
24	5 per cent Clay 1:3:6	Wet	151.6	4.18	59	275	334	5.35	1.28	0	O.

HAW TESTS OF CONCRETE IN SEA WATER.

Reported Condition.			These show little effect after 12 years.	Cement.		Considered as in Abrams' "Design of Concrete Mixtures."				
						Fineness Modulus "m"		w/c	Consistency based on "m" and w/c	Pile No.
10.	1913.	1920.			Name.	For Maximum Strength Table 3.	Test Pile.		R	
erosion	Bad erosion	Eroded and split	..		Mixture—Vulcanite, Alpha and Giant	6.05	5.72		0.68	1
K.	Good	Very Good	*			6.05	5.72		0.74	2
K.	Good	Very good	*			6.05	5.72		1.04	3
erosion	Bad erosion	Bad erosion	..			5.30	5.59	See 10th column	0 59	4
K.	Slight erosion	Very good	..			5.30	5.59		0.70	5
e soft	Slight erosion	Fair	..			5.30	5.59		1.06	6
erosion	Bad	Gone $\frac{HW}{LW}$	..			5.15	5.72		0.66	7
K.	Bad	Bad	..			5.15	5.72		0.83	8
[illegible]	Slight erosion	Poor	..			5.15	5.72		1.08	9
K.	Good	Good	..	No iron	Blanc Stainless	6.05	5.72		0.73	10
K.	Slight erosion	Bad	..			5.15	5.72		1.11	11
K.	Very good	Good	..	High alumina	Atlas	6.05	5.72		0.81	12
K.	Fair	Bad	..			5.15	5 72		1.13	13
K.	Very good	Very good	*	Low alumina	Helderberg and Lehigh	6.05	5.72		0 82	14
K.	Good	Good	..			5.15	5.72		1 09	15
K.	Very good	Very good	*	Iron ore: no alumina	Harmmoor Erz	6.05	5.72		0.79	16
K.	Slight erosion	Bad	..			5.15	5.72		0.97	17
K.	Good	Very good	*	Slag	Universal	6.05	5 72		0.82	18
erosion	Bad	Lost 1916–1920	..			5.15	5.72		1.19	19
erosion	Fair	Bad	..			5.15	5.72		0.93	20
K.	Bad	Gone $\frac{HW}{LW}$	..			....	....		....	22
air	Bad	Very bad	..			....	....		....	23
K.	Fair	Poor	..			....	....		...	24

thirteen years, are now old enough to warrant some pretty definite conclusions. The relative duration of life of the different samples, together with the knowledge of their mixture and different conditions, afford an illuminating chapter in the study of our problem.

To those who are not familiar with these tests, it may be well to state that twenty-four reinforced piles, 16 in. square, 16 ft. long, were cast in January, 1909, with a view of introducing as many variables as possible to throw light on the subject under discussion. In order that the information may be readily digested, your committee has compiled the general facts on one plate (Fig. 2), and it is with the idea of using this largely as a text that the ten headings previously named can best be discussed.

A report before the American Society of Civil Engineers in their meeting in June, 1922*, states that the specimens numbered 2, 3, 5, 6, 10, 12, 14, 15, 16, 17, 18, 20 and 24 are in fairly good condition and specimens 2, 3, 14, 16 and 18 show little or no effect after the severe exposure between high and low water for the period of the thirteen years. The outstanding lessons from these tests are:

1. Aim for impermeability rather than density.
2. Use a rich mix.
3. Use a sufficient amount of water.
4. Avoid admixture of other materials with the cement.

The opponents of the use of concrete construction in sea water have, at various times, used the Aberthaw tests as an argument against the durability of concrete in this service for the reason that a substantial percentage of the test piles did not withstand the test of time.

Those who are familiar with the conditions and the object of the investigations are undoubtedly well aware that certain extreme combinations were used for the express purpose of having some of the samples show rapid deterioration so that relative information might be forthcoming. It will be observed, by again referring to Fig. 2, that in every instance where a rich mix was used with a sufficient amount of water, good results were attained. (See specimens numbered 2, 3, 5, 6, 10, 12, 14, 16 and 18.)

The tests show that the impermeability of the concrete is largely affected by the water content; that dry concrete is exceedingly dangerous; and that an excess amount of water seems to reduce the resistance to salt water.

It is very much regretted that Professor Abrams' pamphlet No. 1† relative to the proportioning of aggregates and water was not available at the time these tests were made. Fortunately, however, the data preserved is of a character which makes it possible to analyze the mixtures that were used in the light of Professor Abrams' disclosure. Strength

*L. C. Wason—Proceedings A. S. C. E., Vol. XLVIII, No. 7, Sept., 1922.

†Design of Concrete Mixtures, Bulletin No. 1. Structural Materials Research Laboratory.

is an essential characteristic of concrete, but far more important is the providing of a concrete which will protect the reinforcing and withstand the chemical actions caused by the penetration of water. It is your committee's opinion that this feature of concrete construction is not, at the present time, having sufficient consideration, and, for that reason, it is being especially emphasized.

As previously indicated, it seems wise to discuss the results of the Aberthaw tests under the ten headings enumerated above:

1. *Impermeability and Density.*—This committee is using the term "impermeability" to mean the relative resistance of concrete to the penetration of water under low pressure. A definition of density does not seem to be necessary. We believe that it is important to differentiate between the two characteristics of concrete since the tests shown on Fig. 2 clearly demonstrate this point. It will be observed that Test Specimen 1, although having greater density than either Test Specimens 2 or 3, and being of identically the same mix (except water content), entirely disintegrated—so much so that the jar of lifting it out and placing it on the pier caused it to split and fall into pieces—while Test Specimen 2 is only slightly pitted and Test Specimen 3 is in exceedingly good condition. It will be observed that Specimen 3 showed no water in the center hole while Specimen 2 has more than Specimen 1. It seems probable, in view of the greater permeability of No. 1 as against No. 2, that the water ran out as well as in, and therefore the height at the time of measurement is not an exact indication of the relative permeability of the material.*

This test may, to some degree, have been affected by the low percentage of reinforcing steel which was used in the piles, namely, two ⅝ in. square twisted bars at two corners. This means that the pile, having apparently been picked up from one end, was subject to high unit stresses, thereby probably causing a number of small cracks which may have had an effect on the permeability test.

Pursuing the analysis of the other tests, it will be seen that the same general principles hold, except in the 4, 5 and 6 specimens, where the maximum density and maximum impermeability seem to coincide. The most durable specimen, namely, No. 5, having a reasonable water content but apparently being quite permeable, shows far the best resistance to the action of sea water.

It is of interest to analyze the mixtures, as shown on Fig. 2, in the light of the information given by Professor Abrams, particularly with reference to the fineness moduli and the quantity of water. This information is shown in the four last columns of Fig. 2.

Here are recorded the actual fineness modulus of each specimen and various characteristics of the mixes derived therefrom on the basis of

*It may be said by way of explanation that the 2½ in. holes, extending down from the top of the piles, were above water during the period of low tide and submerged about 5 ft. of their length during the period of high tide.

the "Design of Concrete Mixtures." We are particularly interested in the water-cement ratio and consistency factor disclosed by this analysis. As heretofore indicated, there seems to be a relationship of importance between the providing of a sufficient amount of water and the permeability of the concrete.

2. *Proportioning and Mix.*—All concrete is predicated on good materials but good materials alone do not ensure perfect results. Your committee draws your attention to the "Design of Concrete Mixtures" as a valuable guide for the proportioning of the different materials. It is important that a sieve analysis of the character described be made, and that the materials be assembled from this information, all as set forth in the treatise mentioned. It is not in the province of this discussion to set forth these methods in detail, but it is a matter of importance to every engineer who desires to produce a concrete that will resist these various destructive agents to give careful study to this problem.

The proportioning of the material shown in Specimens 4, 5 and 6 of the Aberthaw Tests afford a good illustration of unscientific mix. A careful analysis of the aggregates, based on the "Design of Concrete Mixtures" shows that the theoretical quantity of sand to provide a mixture of proper fineness modulus is in excess of 33%. In other words, if the mix had been 1: 1.89: 4.5, greater strength would have been attained for approximately the same amount of cement; or conversely, one quarter of the cement could have been left out to secure the same strength, viz., the mix might have been 0.76: 1.89: 4.5, or a 1: 2 ½: 5.6, which, in turn, is approximately the same as a 1: 3: 6 mix. Since, up to a certain richness, the resistance to sea water action is apparently a function of the percentage of cement in the mortar, it is important that the mortar be made of sufficient richness and so proportioned with the coarse aggregate that the amount is only slightly in excess of its voids. Generally recognized practice indicates that the best mortar mix is about one of cement to one and a half of sand.

The standard mixer provides a means of thoroughly mixing materials. Tests indicate that a 10% increase in strength may be secured by mixing longer than three quarters of a minute to one minute, but general practice seems to indicate that a mix of all the materials for the maximum of a minute is ample to provide excellent concrete.

One of the members of your committee at one time carried on a series of elaborate tests on the mixing of cement in water prior to the introduction of the aggregates. It was found that mixing the cement and water in a small mixer during the period of charging the large mixer with the coarse and fine aggregates, and then introducing the cement and water into the large mixer for one minute mixing, caused an increase of about 20% in the strength of the concrete. This practice has not been followed out for the reason that the experiments were not carried to a point that demonstrated that such favorable results would be obtained under all conditions. There is a principle involved in this, however, that

may be well worthy of consideration, namely, the mixing of the cement in a manner that assures complete hydration.

3. *Quantity of Water.*—It is intimated that in the interests of permanency of construction, strength is not the paramount consideration in the proportioning of concrete. It is therefore important, in using the information in Bulletin No. 1 referred to, to make sure that a sufficient quantity of water is used to provide impermeable concrete. A careful analysis of the proportioning will disclose that the best mix will require the least amount of water in order to make it workable, and this is perhaps one of the simple means of determining whether the mix is approaching its ideal relationship. This feature of concrete making is of so much importance that your committee feels constrained to give it perhaps undue emphasis.

It is pertinent that water ratio and consistency factor be carefully studied in connection with the Aberthaw tests. Factor R, known as consistency factor ratio—and as calculated on p. 16 of the "Design of Concrete Mixtures," all other quantities in the equation being known—is shown in the last column. It may be somewhat misleading due to the fact that the proportioning of the mixture is so far from present recognized standards. This factor is, however, relatively correct and discloses a remarkable uniformity of operation. This, again, points out the skill of the man experienced in proportioning concrete with respect to the uniformity of water content. Attention is directed to Specimens 1 to 9, in which it was apparently intended to mix three different proportions in three degrees of wetness. The consistency factor seems to disclose that this was attained to a remarkably uniform degree.

There is no evidence of deterioration because of excess water except perhaps in Specimen 6, which is clearly over-watered and which did not show as great an exposure resistance as Specimen 5. On the other hand, there are other inconsistencies in the relationship of the two specimens that are a little difficult to explain, namely, the greater density of the No. 6 specimen and the fact that this specimen seems to be much more impervious. The tests clearly indicate that an exceedingly careful watching of the water is necessary and that the mixture should be workable and have a consistency factor approximating unity.

4. *Forms, Spading and Tamping.*—The importance of well supported and rigid forms, which keep the concrete from moving during the period of placing and setting, is so well recognized that it does not seem necessary to do more than mention this in passing. There is, however, an important function of the form which is frequently overlooked. This function is the providing of a smooth face which congregates the cement and the rich ingredients of the mixture to the surface, forming a coating. The smoother the form and the more the tamping and spading, the more effective this protective skin becomes. Not only does the tamping work the air out of the concrete, but it also brings to the surface the materials which seem

to be best suited to increase the impermeability of the mass. It will be observed that this spading cannot be carried on successfully unless the mixture is in an easily workable condition.

5. *Curing.*—This process in the producing of good concrete is frequently overlooked. It is of so much importance that a direct defiance of the laws of curing may vitiate the results with all other conditions perfect. Fundamentally, concrete must have excess water available during the period that it is setting. This is usually largely supplied by the moisture in the air both during the time that the concrete is curing in the forms and after the forms are removed. But better still is the providing of a covering of material which will hold water, keeping such material saturated during at least the first two or three days that the concrete is setting. If this is not possible, frequently the introduction of steam or boiling water in the air which is doing the curing will provide enough moisture to supply the demands of the concrete. Under no conditions should hot, dry steam pipes be used or dry radiation from fires. An exceedingly serious failure occurred not long ago in constructing a large factory building during cold winter months. In the anxiety of the builders to avoid any chance of the concrete freezing, large salamanders were kept burning near the columns immediately after they were poured. Not long after the building was finished, these columns cracked and the outside surface on all columns so heated fell off from a depth of two to six inches, exposing the steel and showing the internal stresses set up by the excess dry heat at the crucial time of curing.

Frequently in a Southern climate where the direct ray of the sun is exceedingly hot, and even in temperate climates during the summertime, severe damage is done to concrete by exposing it to the sun before this initial curing is effected. It is a well demonstrated fact that concrete which sets under water and is not, at any time, subjected to the action of air or excessive heat, has not only greater life but also greater strength. This is a point well brought out in a recent report on the life of materials in sea water gotten out under the auspices of the British Institution of Civil Engineers*. These observations on the life of concrete go back as far as 1885. The compilation, published in 1920, by a committee of engineers appointed by the Institution to assemble data on the effect of sea water on structural materials used therein, is worthy of our serious consideration since it embraces reports from harbor engineers of approximately forty important British and British colonial seaports.

A confirmation of this principle is disclosed in a paper read last June before the American Society of Civil Engineers.† Cubes were cut from the various specimens of piles which had more or less disintegrated, and these were tested for compression strength. Two cubes were cut from each pile, one above the water line and one below the water line. Aside from

*Deterioration of Structures in Sea Water. First Report of the Committee of the Inst. C. E., 1920.

†Tests of Concrete in Sea Water, L. C. Wason, ASCE. Proceedings, Sept., 1922.

Specimen No. 7, which was pretty badly shattered and from which, consequently, it was difficult to secure good cubes, the average strength of the top concrete as against the bottom was 92%. The results of the tests were so uniform, namely, 91%, 92% and 93%, that the rule seems pretty well established.

It is of interest to note that the strengths of these concrete pieces after thirteen years exposure, even in the poorer specimens such as 11 and and 7, ran as high as 3400 lb. to the sq. in. This again demonstrates that there is apparently little relationship between strength and permanency. A strength of 3400 lb. for 1 : 3 : 6 concrete is far above the average result. It will be observed that the admixture of materials other than cement seems to subtract very greatly not only from the life but from the strength of the specimens, since in the same mix, namely, 1 : 3 : 6, specimens 22 and 23 show from 1700 to 2600 lb. compression strength, and the stronger specimen, namely, 22, shows very much less life than the weaker specimen, 23.

It is, furthermore, important in the curing (and, in the event of precast units, in the handling) that care be taken to preserve the skin or outer coating. Information at the present time available leads your Committee to believe that it is unwise to attempt to rub down the exterior of concrete after it is cast unless it is done before initial setting takes place, which, under most conditions, is impracticable. Serious errors of this character are evidenced in concrete fencing and concrete ornamental work where the removal of the surface coating has reduced the impermeability of the concrete and therefore removed the protection against the oxidation of the steel, which, in this character of construction, necessarily must be near the surface.

6. *Proper Location and Percentage of Steel.*—Investigations of the failures of concrete in sea water indicate that a large percentage is due to the oxidation of the reinforcing steel. In many instances the steel is properly placed but the concrete is so permeable that the ordinary thickness of the concrete is insufficient to protect against unusual damage, particularly when subjected to alternate damp and dry air conditions.

The recommendation of the Institution of Civil Engineers' report, based on the information that they have gathered from the various harbor engineers covering an experience of forty years, is that steel embedded from 1½ in. to 2 in. in concrete is safe against disintegration between high and low water. It is in this area that maximum oxidation of steel seems to take place. Below low water a lesser protection is required. The Bureau of Standards* states that "Metal reinforcement is not subject to corrosion if embedded to a depth of 2 in. or more from the surface of well-made concrete." It is important that no metal attachment or metal reinforcement in the pile be exposed in any part of the structure above low tide, since corrosion of any portion of the reinforcement will convey the action through the whole structure.

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*Technologic Paper No. 12. "Action of the Salts in Alkali Water and Sea Water on Cement." Messrs. Bates, Phillips and Wig.

It seems to be the best practice to use not less than ¾ of 1% of steel in members which are subjected to the variations of temperature which occur between submersion and the direct action of the summer sun. In many precast members, such as precast piles, this reinforcement increases to as high as 4% in certain sections. The important consideration with respect to the percentage of steel lies in the stresses to which the precast member will be subjected while it is being put into place. Under almost all conditions this reinforcement is more than ample to take care of the structural strength after the member is in its final position. It is obviously necessary to provide sufficient reinforcement so that no undue stresses will be placed on either the steel or the concrete at any time during the process of driving or placing the member; otherwise, initial cracks and breaking of the surface coating will occur.

7. *Avoidance of Seepage or Drainage Action.*—Apparently there is no action so detrimental to a concrete structure as the passage of water and the various impurities carried thereby through concrete. This is a well recognized principle in the care with which engineers now waterproof all walls or buttresses which may in any way be subjected to hydrostatic pressure. This is of a special importance where laitance or other impurities form an opening to let the water penetrate first. If possible, drains should be provided so that difference in water pressures may be avoided.

It is apparent that great care should be taken in making breaks in the pouring or in the joints where laitance may be deposited. It is recommended that the work be so laid out that each section will be completely poured in one run, thereby bringing all the laitance or impurities to the surface where they can be worked off.

8. *Avoid Placing the Concrete Where it is Subject to the Alternate Action of Air and Water During the Period of Setting.*—The foregoing statement of the chemical actions which apparently take place between sea water and cement in concrete leads us to believe that this action will be greatly increased if the material is subjected to the alternate action of sea water and air before the complete hydration of the cement takes place. As might be expected, the saturation and drying apparently bring on crystallization with its attendant swelling and disintegrating mechanical effect. Experience has taught that practically all concrete which is placed without regard to this rule has shown serious disintegration.

One authority from the Great Lakes has indicated that the use of heavy cotton sacking inside the forms to protect the "green" concrete from the washing action and, to a certain degree, the chemical action, of the water (in this case fresh water) has entirely obviated this difficulty. It is your Committee's opinion that this method of protection will not avail in salt water, although no experiments, so far as is known, justify this conclusion.

9. *Exterior Protection of Concrete.*—The limitation of concrete with respect to wear is so well known that it is obvious that if heavy ice floes,

flotsam or other abrasive action from boats or ships are to be encountered, suitable protection should be placed on the exterior. These are usually cheaply provided in some type of wood and should consequently be placed as low in the water as possible so maximum life may be attained. It is recommended that this protection be so designed that no watertight pockets are provided which will retain moisture when the tide falls. During the cold weather, the freezing of these pockets has a disruptive effect both on the concrete and on the protection. Evidences of disintegration of this character are shown in some of the reports made on piles at Atlantic City where copper or galvanized sheet iron has been used as a protection or form for the placing of "green" concrete.

It is the practice of some engineers to coat with some character of oil product that portion of the structure which is subjected to alternate high and low tide action. This is ostensibly for the purpose of keeping the moisture from penetrating into the surface of the concrete. Wax tailings is a product usually employed for this service and, in the experience of your committee, seems to have no deleterious effect. It is doubtful, however, whether there is any particular advantage in the use of these protections. It is observed that barnacles or sea growth usually form on concrete when oil is not used. Frequently, (as in the test pieces discussed), the oil in the water has coated the exterior of the piles. Apparently this keeps off the barnacles but, in turn, effects a coating in itself. None of these protections, however, are of much avail unless the concrete is of good character.

10. *Cement.*—The finding of the Bureau of Standards with respect to the composition of cement best suited to sea water service indicates that concrete of high iron content and high or normal alumina content did not show marked difference in tensile strength where exposed to fresh or salt water for a period of two years. Other cements of various compositions show signs of disintegration after a few weeks. "All cement resisted disintegration in the sea water better in mortar mixtures than in the form of neat briquettes."

The Southern Pacific engineers hold that a cement low in alumina and fairly high in iron is desirable. As previously stated, their rule is that the percentage of iron content subtracted from the percentage of alumina content should be less than four.

It is interesting to note in the Aberthaw Tests that Specimen 15 is the only 1 : 3 : 6 mixture that has stood up well during the thirteen years of exposure, and that the cement used in this specimen was low in alumina. It is to be observed, too, that the same weak mix in the iron ore, or no alumina, cement, that is, Specimen 17, gave a very unsatisfactory resistance to the action of sea water. The same statement holds true in the weak mix and slag cement. On the other hand, the rich mixtures in all of these three combinations show excellent results.

An analysis of all the cements used is shown in Fig. 3. It will be noted that the low-alumina cements come well within the Southern Pacific

FIG. 3.—ACTION OF SEA WATER ON CONCRETE.

Chemical Analyses of Cement.

	White Portland Cement	Average Alumina Cement	High Alumina Cement	Low Alumina Cement	Iron Ore Cement	Cement Made of Slag
Loss on Ignition	1.69%	0.96%	1.06%	1.04%	0.91%	2.82%
Silica (SiO_2)	24.58	22.08	21.46	23.40	24.28	20.42
Alumina (Al_2O_3)	8.22	7.21	8.50	5.61	0.94	8.04
Iron Oxide (Fe_2O_3)	0.29	2.57	2.44	2.37	9.08	3.04
Lime (CaO)	62.70	62.60	61.64	62.90	62.12	62.16
Magnesia (MgO)	1.11	2.74	2.58	2.51	0.43	1.63
Sulphuric Anhydride (SO_3)	1.32	1.56	1.75	1.53	1.75	1.73

Analysis of hydrated lime

Loss on ignition	1.32%
Silica and insoluble matter	18.73
Carbon dioxide	1.51
Alumina and iron oxide	0.68
Lime	45.88
Magnesia	31.62

Examination of Sand and Broken Stone.

The sand, which was very fine, was clean and of good quality. As used, it contained 4.6% moisture. Dry, it averaged 97.18 lb. per cu. ft. The voids measured 34.2%. By weights the sand passed different meshes as follows:

No. 100	4.8%	No. 10	91.0%
50	24.0	8	93.4
30	52.0	6	96.1
20	73.4	¼ inch	100.0
16	86.4		

The stone was a broken trap, of very good quality, containing 50 per cent of voids by volume. It weighed 90.24 lb. per cu. ft. The fineness in passing sieves was represented by weights as follows:

⅛ inch	0.25%	½ inch	25.25%
$\frac{3}{16}$	0.50	¾	53.0
¼	1.75	1	80.75
⅜	9.75	1½	100.0

specifications, namely, the difference between 5.61 alumina and 2.38 iron oxide is under the factor 4, while in the slag cement, this factor increased to 5.

ALKALIES.

The U. S. Bureau of Standards is investigating the effect of the action of alkali on concrete and has done some preliminary work over a period of several years by installing concrete blocks and drain tile in various localities, principally in the West. The Structural Materials Research Laboratory, Lewis Institute, Chicago, also has installations of concrete specimens covering a wide range of conditions in several Western localities. These studies are still going on and at this time no definite recommendations can be made, but the conditions which are being studied may be considered as representing some of the accelerated forms of destructive agents, and a study of the results may throw some light on the questions which have come up in connection with disintegrated concrete, which has been placed in localities that are not considered to have excessive quantities of injurious salts.

The results of some of these investigations have been published in a Third Progress Report, as Technologic Paper Number 214 of the Bureau of Standards, and although the conclusions are to be considered only as tentative, they will serve to partially express the feeling of this committee in its studies up to this time.

(a) "Results to date indicate that materials of good quality and proper workmanship are of great importance in the production of concrete which is to be exposed to alkali soil and waters.

(b) "Extent and rapidity of disintegration in sulphate waters depends upon concentration of salts in waters to which the concrete is exposed.

(c) "In blocks containing reinforcing rods disintegration appears to be aided and accelerated in some cases by corrosion of embedded steel and consequent cracking of the concrete, as has been observed in some reinforced concrete structures exposed to sea water.

(d) "Structures placed in alkaline soils or exposed to alkaline seepage waters should be given all possible protection by drainage. Disintegration is brought about by those salts which are in solution as indicated by analyses of water samples, while the soil analyses merely represent reserve supplies which may bring about changes in the existing solutions with changing conditions of rainfall, flooding, etc.

(e) "For the same concentration of soluble salts and for the same aggregates, resistance of mass concrete to alkali action

appears to vary with cement content of richness of mix, within the limits employed in these tests.

(f) "Disintegration may be manifested in sulphate waters by physical disruption caused by expansion resulting from the crystallization of salts in the pores, but it is primarily due to chemical action between the salts in solution and the constituents of the cement. In the case of dense tile of low permeability exposed to sulphate waters, disintegration may occur at or just inside the surface skin and progress into the wall of the tile."

As previously stated, this committee is using the term "impermeability" to mean the relative resistance of concrete to the penetration of water under low pressure, as this seems to be a very important factor to be considered in designing concrete mixtures. Further investigation may show that the rate of absorption can be used as a measure of the durability of concrete when subjected to alkali or frost action. The studies of concrete in alkali soils, and also disintegrated concrete which has not been subjected to strong alkalies or acids, have shown the importance of permeability as a quality to be used as a guide rather than porosity or density. It has been found that permeable concrete due to lean mixtures of very dry consistencies or improper curing is more susceptible to unusual attacks of disintegrating agents than impermeable concrete.

The foregoing rules pertaining to the selection of materials, grading, richness of mix, curing, protection of steel, drainage, forms, etc., are equally applicable to the production of concrete to withstand the action of alkali.

In order to ensure the very best results and obtain an impermeable concrete, care must be exercised in selecting materials having proper grading and to make a mixture containing enough cement not only to provide sufficient strength, but to make an impermeable concrete, which will withstand the action of most disintegrating agents to which it may be exposed. This may mean that what has been considered a very rich mix will need to be used even though it produces strength in excess of the demands. The concrete must be placed in the forms in such a way that the materials are not separated and that the concrete which may be exposed to any disintegrated agent will be impermeable.

Provision for adequate drainage is an important factor. The possibility of water percolating through retaining walls of similar structures, must be eliminated.

The reinforcing steel should be placed at a sufficient distance from the surface and the quality of the concrete must be impermeable enough to protect the steel from moisture. The concrete must not be made so dry that the entire surface of the steel is not perfectly covered, as air pockets around the steel will cause local rusting.

The committee has not made an exhaustive study of the uses of in-

tegral waterproofing compounds, but it is felt that when they are used the same amount of care should be exercised in designing the mixture and in placing the concrete that would be used otherwise, keeping in mind that the ultimate aim is to produce an impermeable concrete having sufficient strength to fulfill all requirements.

ACTION OF OILS, HIGH TEMPERATURES AND ACIDS.

1. *Oil.*—Floors and walls of various buildings used by the oil industry are subjected to a great extent to action of mineral oils because of leakage. The most important consideration in such concrete is to use a thoroughly mixed and well-worked concrete. It is found that with a 1:2:4 mix, using portland cement, clean river sand, and a coarse aggregate of gravel or crushed stone not exceeding 1½ in. in maximum size, thoroughly mixed and well trowelled, the oil has very little, if any, effect on the concrete. In cases where deterioration has occurred this has been so slight as to be practically negligible.

In some instances a finish coat of one to one and one to two cement and sand has been used, and it is found that there is a tendency for the oil to gradually work through this finish coat and destroy the bond between it and the concrete.

Concrete oil tank construction to date has been rather limited in scope, but indications are that for heavy crude and fuel oil tankage there is little if any deterioration of the concrete, and seepage of oil is extremely small. For the various grades of refined oil, deterioration is not serious, but seepage is much more rapid than in the case of heavy oils. A number of commercial compounds are available on the market for coating the interior of such tanks, and these have been used with more or less success.

2. *Heat.*—The use of concrete core walls in settlings for boilers and similar apparatus is more or less common, various methods for protection for the concrete being employed. For furnace temperatures around 800° to 900° a protection consisting of one layer of common brick and one 4½ in. layer of fire brick is sufficient. For temperatures higher than these it is customary to use an air space or a layer of insulating brick or asbestos insulation next to the concrete, and then fire brick from 4 to 18 in. thick, depending on the furnace temperature. Means are sometimes provided for ventilating the interior of the setting by inserting small ventilating pipes.

With the above construction it is sometimes found, especially where no insulating material is used, that the concrete burns to a powder on the surface, but the penetration is not sufficient to affect the strength of the construction.

3. *Acid.*—Concrete supports and foundations are used in a great many cases for tanks storing acids, and for treating units used in various chemical processes involving the use of acids.

Concrete foundations are also used for pumps and other mechanical

construction involved in these processes, and these foundations are subjected to acid through leakage.

In some cases concrete floors and walls are used in buildings connected with acid process work.

It is found that wherever sulphuric, phosphoric, nitric, hydrochloric or muriatic acids come in contact with concrete they exert a considerable deteriorating effect. No data has been secured in this investigation relative to the action of other acids.

In a great many cases foundations are subjected to one or the other of these acids which may be present in ground water. In any case it is important that acid shall not come in contact with the concrete until it has thoroughly set, and in case of foundations this can be effected by digging the ditch somewhat deeper than the foundation forms, and keeping the ditch pumped dry until complete setting has occurred.

As a protection against the acid action a coat of pitch or heavy asphaltum applied on the surface of the concrete is of great value where there is no possibility of mechanical wear breaking this coating and permitting the acid to penetrate to the concrete. Where there is mechanical wear, a layer of acid brick set in an acid-proof bed should be used.

DISCUSSION.

Mr. Loney. N. M. Loney.—I would like to ask Mr. Upson what consideration was given to the effect of temperatures. Prof. Abrams yesterday spoke of the arches which are always in warm water. I have had some experience and was led to believe that largely the action of frost in the winter time between high and low water was what caused a great deal of the damage.

Mr. Upson. M. M. Upson.—In my presentation, I have necessarily left out a great deal of information contained in the paper. One point that is made in the text is that all construction of this character which has to do with water where there is ice or objectionable flotsam should have some mechanical protection such as a lagging of wood or perhaps copper to take the abrasive action.

Mr. Loney. Mr. Loney.—That was the point I was trying to make, that apparently in your report that was dwelt on as a means of protection against mechanical abrasion, whereas I believe it has a valuable influence in that frost between high and low tide will not penetrate through a sufficient thickness of wood.

Mr. Upson. Mr. Upson.—There is no idea of keeping the frost away from the concrete. As a matter of fact, we find from actual examination that the action of salt water on concrete seems to be stimulated by increased heat and that the problem is more difficult of solution in southern than in northern waters. The actual attack on impermeable concrete does not seem to be augmented by frost, provided the concrete is impermeable.

Mr. Spiker. W. C. Spiker.—I understand that the committee is primarily giving attention to concrete in salt air or salt water, but it has also mentioned incidentally concrete in fresh air. Is it studying that problem also in that committee?

Mr. Upson. Mr. Upson.—We are; we expect to treat that in our next report. We find that there has been quite a number of disintegrations of piers in fresh water, and we find a good many actions of that kind.

Mr. Spiker. Mr. Spiker.—I am more interested in that than in the salt air proposition. I know of some bridges, for instance, especially bridges built out of limestone concrete, which have very appreciably disintegrated, and there is no unanimity of opinion as to why the disintegration took place. There is a very wide difference of opinion on this whole subject, an almost arbitrary, positive difference of opinion.

Mr. Upson. Mr. Upson.—We hope that any members who have any information on this subject will turn it over to us, because the more information we have, the more effective we can be in discharging our duties.

REPORT OF COMMITTEE G-4, ON NOMENCLATURE.*

Since the 1922 annual meeting of the American Concrete Institute Committee G-4 has taken steps to secure closer contact with the work of the entire Institute. With the approval of the Board of Direction, it has requested each committee to appoint one of its members to bring before Committee G-4 any definitions which have been adopted or which are under consideration by the committee which he represents. The response to this request has been of assistance to Committee G-4, but fuller co-operation is needed than has yet been obtained. In this connection the list of definitions submitted by Committee P-1 is attached as an Appendix to this report.

Attention is called to the fact that a large part of the report submitted and published one year ago by Committee G-3 on "The Form but not the Substance of Standards" duplicates a part of the report of Committee G-4, which was published in the "Proceedings" four years ago and adopted one year later by letter ballot of the Institute. The demarcation between the functions of a nomenclature committee and a committee on form of standards cannot well be a sharp line. Committee G-4 requests instructions from the Board of Direction which will define its scope.

This committee has reconsidered and reaffirms the statement of the basis of its work as laid down in the 1919 "Proceedings," and the statement is here quoted:

> (1) To make the definitions fundamental and as broad as possible, with recommendations as to expansion to fit special needs and notation as to the most common usage, but to avoid needless restriction of the meaning of the word which would make it apply to only one or more phases of a larger possible meaning.
>
> (2) To adopt as far as possible the definitions already accepted by other societies, authors, and by standard practice in engineering.

The definitions from the 1919 report, together with some additions and modifications are here repeated, arranged in alphabetical order. The new definitions have been taken from the tentative definitions published in the 1921 report. Written discussion of these definitions has been received from a number of members of the Institute. This discussion has been given consideration and as a result the modifications above mentioned have been made. Where changes in the definitions given in the 1919 report are proposed in the present report of the committee the changed portions are

* Adopted by letter ballot ordered at tenth annual convention, 1923.

italicized in the present report except where the only change is an omission, and in those cases the omitted portions are included in brackets. For the assistance of the members of the Institute in voting on the report an outline characterizing the modified and added definitions is made. The numbers in this outline refer to the numbers of the listed definitions.

1. New definitions added: Numbers 5, 7, 14, 21, 27, 40, 56, 59, 64, 68, 71, 79, 80, 99, 101, 104, 106, 109, 111, 116, 120, 124, 128, and 131.

2. Changes in or additions to the substance of definitions given in 1919 report, page 373: Numbers 25, 34, 35, 36, 37, 43, 51, 69, 73, 78, 98, 126, and 135.

3. Changes in wording which do not change the meaning intended in the definitions given in the 1919 report: Numbers 1, 45, 60, 62, 63, 81, 84, 88, 91, 94, 114, 123, and 133.

4. All other definitions in the 1919 report remained unchanged.

5. Definitions of composition flooring, granolithic finish, and spaded finish are referred to Committee C-2 for recommendations as to modification.

6. Definitions of column capital and column head are referred to Committee E-1 for recommendations as to modification.

7. The list published in the 1921 report of words which Committee G-4 has been requested to define will be referred to the proper committees of the Institute for definitions.

8. Definitions submitted by Stanton Walker, representing Committee P-1, are presented for information and discussion of the Institute. These definitions will be taken up for action by Committee G-4 during the coming year.

DEFINITIONS.

Italicized sections are changes from 1919 definitions. Material in brackets is that which it is proposed to omit, where the only change is an omission.

1. *Aggregate*—The inert material used in making concrete; *in general, aggregate consists of sand, pebbles, crushed rock or similar materials.* (See coarse aggregate and fine aggregate.)

2. *Angle Fillet*—A triangular strip of wood which is placed in the angle of a form for concrete in order to produce a chamfered edge in the concrete.

3. *Bank Run Gravel*—Normal product of a gravel bank including pebbles and sand in varying proportions.

4. *Belt Course*—A continuous horizontal course in the outside wall of a building projecting slightly from the elevation and usually molded in order to produce an architectural effect.

5. *Bench Wall—The abutment from which an arch springs.*

6. *Billet-Steel Bars*—Bars rolled from new billets.

7. *Bond*—(1) *The resistance which is offered to the slipping of a reinforcing bar through the concrete in which the bar is embedded; the bond is measured in terms of the applied force per unit of surface area of the bar.*

(2) *In masonry the mechanical disposition of stone, brick, or other building blocks by overlapping to break joints and to bind the wall together.*

8. *Book Tile*—A tile designed to be held in place by means of crude tongues and grooves formed on the edges of the tile, and deriving its name from its resemblance to a book.

9. *Bottom Form*—The form unit used to define the bottom of a structural member, as a beam or girder.

10. *Buggy (Concrete)*—A two-wheeled hand cart used for the transporting of freshly mixed concrete.

11. *Capital*—See column capital.

12. *Cement*—See hydraulic, natural, portland, puzzolan and sand cements.

13. *Cement Wash*—A coating consisting of a mixture of cement and water applied to concrete surfaces (generally with a brush) to reduce permeability, or to give a uniform color.

14. *Centering—A temporary support used in arch or dome construction. (Also called centers.)*

15. *Chats*—A crushed rock of flinty character obtained as a by-product in the preparation of lead and zinc ores for smelting. It ranges in size from about ¼ in. to ⅜ in.

16. *Chute (Concrete)*—An arrangement of troughs or tubes through which freshly mixed concrete is transferred from one place to another.

17. *Chuting (or Spouting) Concrete*—The transporting of concrete by gravity through troughs or tubes.

18. *Cinders*—The hard waste product of the combustion of coal.

19. *Clamp*—See form clamp.

20. *Coarse Aggregate*—The coarser inert material used in making concrete, usually considered to include that material which is retained on a sieve having four meshes per lin. in. The upper limit of its size depends on various conditions but it seldom exceeds three in.

21. *Column—A vertical compression member whose length exceeds four times its least horizontal dimension.*

22. *Column Capital*—An enlargement of the upper end of a column generally used in connection with flat-slab floors. (Referred to Committee E-1 for recommendations.)

23. *Column Head*—See column capital.

24. *Composition Flooring*—A floor formed of various chemicals and a filler mixed with water and laid in a plastic condition, troweled smooth and then allowed to set hard. (Referred to Committee C-2 for recommendations).

25. *Concrete*—A compound of gravel, broken rock, or other aggregate, *bound together by means of* hydraulic cement, coal tar, asphaltum, or other cementing materials. Generally, (*always in the specifications of the American Concrete Institute*) when a qualifying term is not used, portland cement concrete is understood.

26. *Concrete Projector*—An apparatus used for forcibly depositing mortar or concrete from a nozzle by means of air or steam pressure. The concrete materials ordinarily are brought from the mixer to the nozzle through a hose.

27. *Construction Joint—A joint or break between successive deposits of concrete, usually to facilitate construction.*

28. *Continuous Action*—The working together of two or more flexural members (columns, beams, or slabs) to resist mutually a moment applied to one or more of the members.

29. *Contraction (or Expansion) Joint*—A joint or opening provided between two masses of concrete to allow for variations of volume.

30. *Crusher-Run Rock*—The unscreened output of the stone crusher.

31. *Crushed Slag*—Air-cooled blast-furnace slag of sizes included under "Coarse Aggregate".

32. *Crushed Stone*—Crushed natural rock of sizes defined under "Coarse Aggregate".

33. *Curtain Wall*—A wall which does not itself form a supporting member of the building of which it is a part.

34. *Cyclopean Concrete—Concrete in which stones weighing more than 100 lb. are individually embedded.* See also rubble concrete. (Replaces "rubble stone or cyclopean concrete".)

35. *Deformed Bar*—A reinforcing bar which has projections or indentations *on* its surface designed to furnish *anchorage* or *additional bond* between the metal and the concrete.

36. *Dropped (or raised) Panel—The structural portion of a flat-slab which is thickened throughout an area surrounding the column capital to provide an increased resistance to compression or shear.*

37. *Expanded Metal—A mesh or lattice work made of sheet metal; used for lathing, reinforcing concrete in building construction, etc.*

38. *Expansion Joint*—See contraction joint.

39. *Fabric*—See wire fabric and expanded metal.

40. *Faced Surface—A surface produced by placing a special aggregate next to the forms and contiguous with the body concrete, or by applying a layer of another material after the completing of the concreting.*

41. *Fine Aggregate*—The finer inert material used in making concrete, usually considered to include that material passing a sieve having four meshes per lin. in.

42. *Finish*—See granolithic, rubbed, sand blast, tooled, and washed or scrubbed finish.

43. *Flat-Slab*—A flat concrete *slab* having reinforcing rods extending in two or more directions, and having no beams or girders to carry the loads to the *supporting* columns. Various trade names are applied to flat slab floors using proprietary systems of reinforcement.

44. *Footing*—See pedestal footing and pile footing.

45. *Form*—A structure (or a structural unit which, in conjunction with other units, make up a structure) *used* to receive concrete before it has hardened and to mold it to the designed shape. *Sometimes referred to* as false work or centering.

46. *Form Clamp*—An arrangement of wood, steel, or iron members designed to hold forms together to resist the pressure of wet concrete against their sides.

47. *Form Girt*—A longitudinal timber laid cross-wise under the joists and used as a girder to support the floor formwork.

48. *Form Jack*—A vertical support for the formwork of beams which is provided with a cross-piece at the top and two short diagonal braces.

49. *Form Joist*—A longitudinal timber placed under the panels of floor formwork.

50. *Form Ledger*—A horizontal timber used to brace the posts in floor formwork.

51. *Form Mud-Sill*—A timber member laid directly upon the [surface of the rough] ground to provide a bearing for the posts of the floor formwork.

52. *Form Panel*—A form unit used to define a flat surface of considerable extent, e. g., a slab "bottom form" or a wall "side-form".

53. *Form Post*—A vertical timber used to support the formwork of floors.

54. *Form Re-Stud*—See shore.

55. *Form Ribband*—A horizontal timber used to hold the bottom of beams side-forms in place.

56. *Foundation Bed*—*The surface on which the foundation of a structure rests.*

57. *Girt*—See Form Girt.

58. *Granolithic Finish*—A finish applied to concrete floors which exposes to view a surface layer of particles of coarse granite, or of other hard enduring rock, bonded with cement "mortar". The finish may be formed by troweling while wet to bring the crushed rock to the surface or by surface grinding after the concrete has hardened. Apparently, the name has been derived from the use of the crushed granite, in the surface layer.

(Referred to Committee C-2 for recommendations.)

59. *Gravel*—*Loose material containing particles larger than sand,*

resulting from natural crushing and erosion of rocks. (See sand and bank run).

60. *Grout* (noun)—The material resulting from mixing cement and water, or cement, sand and water *to a* fluid consistency.

61. *Grout* (verb)—To fill a cavity or make a joint with grout.

62. *Handle Nut*—A nut *with a forged handle* to obviate the necessity for using *a wrench;* much used in formwork and other temporary construction.

63. *Hooping*—Reinforcement in the form of hoops or *wire spiral placed within a concrete column. The hooping is designed to resist horizontal tensile stresses in the column and assists in holding* the column bars in place during the placing of the concrete.

64. *Hydraulic Cement—Any cement having the property of setting and hardening under water.*

65. *Insert*—A socket usually of cast or malleable iron, either slotted or tapped to receive bolts for attaching shaft hangers, sprinkler pipes, or other articles, to the concrete.

66. *Jack*—See form jack.

67. *Joist*—See form joist.

68. *Lagging—Strips used to carry and distribute the weight of an arch to the ribs or centering during its construction.*

69. *Laitance—The extremely fine particles which separate from freshly deposited mortar or concrete and collect on the top surface.*

70. *Ledger*—See form ledger.

71. *Loam—A soil consisting of a natural mixture of clay and sand, the latter being present in sufficient quantities to overcome the tendency of the clay to form a coherent mass.*

72. *Mixer*—See pneumatic mixer, and concrete projector.

73. *Mortar*—A material used in a plastic state, becoming hard in place, to bond together such materials as brick, stone, tile, gypsum blocks, terra cotta, etc., in walls, partitions, columns, foundations, piers, floors and roof arches, etc., *also to form wearing surfaces.* The word "mortar" is used without regard to *its composition,* defining its use as a binding *or wearing material,* as contrasted with the words "stucco" and "plaster". *An exception to this statement is the case where small aggregate less than one-fourth in. is mixed with the binding material used to make mortar briquettes or cubes for test purposes.*

74. *Mud-Sill*—See form mud-sill.

75. *Natural Cement*—The finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature sufficient only to drive off the carbonic acid gas.

76. *Negative Reinforcement*—Reinforcement so placed as to take stress caused by negative bending moment.

77. *Panel*—See dropped panel and form panel.

78. *Pebbles—Naturally rounded coarse aggregate.*

79. *Pedestal Footing—A member supporting a column in which the*

projection from the face of the column on all sides is less than one-half the depth of the member.

80. *Pile Footing—A footing which rests upon piles. The heads of the piles may or may not be embedded in the footing.*

81. *Plaster*—A material used in a plastic state to form a hard covering for the interior surface, walls, ceilings, etc., of any building or structure. The word "plaster" is used without regard to *its composition,* defining only its use and location [of use] as contrasted with the words "stucco" and "mortar".

82. *Plums*—Stones of large size, usually over 3 in., which are added to the concrete during placing.

83. *Pneumatic Mixer*—A combination of machine and pipe line in which concrete is mixed and conveyed simultaneously by means of compressed air.

84. *Point* (verb)—To apply mortar to a joint in a masonry or concrete structure; or more generally, to apply mortar or plaster anywhere to a structure in *finishing* lines or surfaces.

85. *Potland Cement*—The product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

86. *Post*—See form post.

87. *Projector*—See concrete projector.

88. *Punching Shear*—The shear in a structure *on* the periphery of a strut or other member applying a concentrated load. [Punching shear may be critical in slabs or other thin members.]

89. *Puzzolan Cement*—The finely pulverized product of a mechanical mixture of volcanic ashes or basic blast-furnace slag with powdered slaked lime. When slag is used this is sometimes known as slag-cement. This should not be confused with portland cement manufactured from a mixture of slag and limestone but calcined subsequent to mixing.

90. *Precast Concrete*—Concrete cast in separate units which are later assembled into a structure, (See unit construction).

91. *Rail Steel Bars*—Bars rerolled from *railway* rails.

92. *Raised Panel*—See dropped panel.

93. *Reinforcement*—The metal (generally steel) placed in a concrete member to assist in resisting the stresses which come upon the member. (See also negative reinforcement.)

94. *Reinforced Concrete*—Concrete in which *tension or compression reinforcement* is embedded in such a manner that the *concrete and the reinforcement act together* in resisting stresses.

95. *Reinforcement Spacer*—A device for maintaining the reinforcing bars or units in the proper positions relative to each other and to the boundaries of the members.

96. *Re-Stud*—See shore.

97. *Ribband*—See form ribband.

98. *Rubble Concrete—Concrete in which stones weighing not more than 100 lb. are individually embedded.* (See also cyclopean concrete.)

99. *Rubbed Finish—A surface produced by rubbing with carborundum or with cement bricks or wooden floats to remove form marks and irregularities.*

100. *Sand*—The finely divided material generally of a siliceous nature resulting from the reduction of rock by natural forces to the size included under fine aggregate.

101. *Sand Blast Finish—A surface produced by the wearing effect of a sand blast.*

102. *Sand Cement, Silica Cement*—The finely pulverized product resulting from the intimate mixing and grinding in varying proportions (generally one-half of each) of siliceous sand or other siliceous material and portland cement.

103. *Screed*—A guide (usually of wood) used to gage the finishing of mortar or concrete to required surface or grade.

104. *Screen—A metal plate with circular perforations used for separating granular materials into different sizes.*

105. *Screenings*—See slag screenings and stone screenings.

106. *Set*—(noun)—*A change from a plastic to a solid or hard state.*

107. *Shore*—A prop or support. A temporary rough timber used to support the weight of a floor after the forms are stripped and until the concrete has thoroughly hardened.

108. *Side-Form*—The form unit used to define the side of a structural member, as a beam or girder.

109. *Sieve—A woven wire cloth with square openings used for separating granular materials into different sizes.*

110. *Silica Cement*—See sand cement.

111. *Silt—A deposit of mud or fine earth from running or standing water.*

112. *Slag*—See crushed slag.

113. *Slag Screenings*—Crushed air-cooled blast furnace slag of sizes defined under "Fine Aggregate".

114. *Sleeper*—A strip of wood placed above or in a concrete slab to serve as a nailing strip for wood flooring. *The term "screeds" is sometimes used (inaccurately) in this sense.*

115. *Sleeve*—(1) A tube or box of wood or metal placed on or in the forms of a concrete floor or wall in order to provide a hole for the passage of a pipe, bolt, or wire, or to act as a spacer for the forms.

(2) A short length of pipe used to hold in alignment the butted ends of compression reinforcing bars.

116. *Soil—A mixture of fine earthy materials with more or less organic matter, resulting from the growth and decomposition of vegetation or animal matter.*

117. *Spacer*—See reinforcement spacer.

118. *Spiral Hooping*—See hooping.

119. *Spouting Concrete*—See chuting concrete.

120. *Standard Sand—Natural sand from Ottawa, Ill., screened to pass a sieve which has 0.0335-in. openings and retained on a sieve which has 0.0223-in. openings provided that not more than 5 g. pass the latter sieve after one minute continuous sieving of a 500 g. sample. This sand is used as aggregate in standard strength tests of cements.*

121. *Stirrup*—A reinforcing unit (vertical or inclined) used in the web of a flexural member to resist tensile stresses set up in the beam by a combination of shear and longitudinal tension.

122. *Stone Screenings*—Crushed natural rock of sizes defined under "Fine Aggregate".

123. *Stucco*—A material used in a plastic state to form a hard covering for the exterior walls or other exterior surfaces of any building or structure. The word "stucco" is used without regard to its [the] composition [of the material], defining only its use and location [of its use] as contrasted with the words "plaster" and "mortar".

124. *Tooled Finish—A surface produced by tooling with a bush hammer, crandall or other desired tool to a uniform and finished surface.*

125. *Tooling*—The finishing of a concrete surface with a special tool in a manner to show the marks of the tool.

126. *Tremie—A water-tight pipe of suitable dimensions used generally in a vertical position for depositing concrete under water; a tremie reaches to the surface where the concrete is being deposited and is generally equipped with a funnel shaped hopper at the upper end.*

127. *Unit Construction*—The utilization of precast concrete members in building construction. (See precast concrete).

128. *Voids—A term applied to the spaces between grains of sand or to the spaces between the fragments of gravel, crushed stone, or other aggregates. The voids are expressed as a percentage of the gross volume of the material. The term is also applied to the spaces throughout a mass of concrete, mortar, or paste that are filled with air or water.*

129. *Wall Beam*—A beam which spans between exterior columns of a structure and which is used as a supporting member for the floor slab at its outside edge. Frequently the wall beam carries the curtain wall for the story above.

130. *Wall Bolt*—An iron bolt threaded at both ends used in formwork to bolt the forms of the two sides of a wall together; it is sometimes used in column forms in a similar manner.

131. *Washed or Scrubbed Finish—A surface produced by rubbing or scrubbing concrete to expose the aggregate.*

132. *Weep Hole*—A hole in a wall, floor, or other structure, made for the purpose of providing drainage.

133. *Well*—A vertical compartment or shaft in a building or a series of openings in vertical alignment through the floors of the building; "elevator-well" when *provided for the operation of an elevator;* "stairwell" when used to enclose a stairway.

134. *Wing Nut*—A nut with two opposite projecting wings so ar-

ranged as to obviate the use of a wrench; used in formwork and other temporary construction work.

135. *Wire Fabric*—A [form of concrete reinforcement] *mesh* composed of parallel longitudinal wires tied together at intervals by transverse or diagonal wire. The intersecting wires are sometimes welded together (also known as "wire cloth" or "wire mesh").

Committee G-4 requests that a letter ballot be sent to the members of the Institute for action on the proposed additions and changes outlined in items 1, 2 and 3. No action is requested on the other items of the report but written discussions of these proposals will be appreciated by the Committee. This report has been submitted to the members of the Committee for ballot of whom 5 have voted in the affirmative, 0 in the negative and 0 have not voted.

G. A. HOOL,
J. H. LIBBERTON,
A. B. MCDANIEL,
W. A. SLATER, *Chairman*,
F. A. HITCHCOCK, *Secretary*.

APPENDIX I.

REPORT TO COMMITTEE ON NOMENCLATURE OF THE AMERICAN CONCRETE INSTITUTE.

By Stanton Walker.

(For Committee P-1 of the American Concrete Institute.)

Concrete Products.

1. *Concrete Building Block, Brick and Tile.*

Precast concrete units for use in masonry construction.

(a) *Hollow concrete building block.*

A concrete block containing one or more air spaces. Units commonly designated as block have a minimum cross-sectional area of concrete equal to 60 per cent or more of the gross cross-sectional area.

(b) *Two-piece concrete building block.*

A concrete block of such shape that two units, which interlock or are mechanically tied together and form air spaces between them, are required to give the full thickness of wall.

(c) *Solid concrete building block.*

A concrete block having no air spaces.

(d) *Hollow concrete building tile.*

A light-weight concrete block having one or more air spaces. Units commonly designated as tile have a minimum cross-sectional area of concrete less than 60 per cent of the gross cross-sectional area.

(e) *Concrete brick.*

A solid rectangular concrete block usually about 2¼ by 3¾ by 8 in. in size.

2. *Gross Cross-Sectional Area.*

(a) *One-piece unit.*

The gross cross-sectional area of a one-piece unit is the product of the length times the width of the unit as laid in the wall. (No allowance is made for air spaces in hollow units.)

(b) *Two-piece unit.*

The gross cross-sectional area of a two-piece unit is the product of the length times one-half the thickness of the wall for which the block is designed.

3. *Minimum Cross-Sectional Area.*

The minimum cross-sectional area of a concrete building unit is the minimum area of concrete in a section parallel to the bearing face of the unit in the wall.

4. *Percentage of Air Space.*

The percentage of air space in a hollow concrete unit or tile is equal to the ratio of the difference of gross and minimum cross-sectional areas to the gross cross-sectional area multiplied by 100.

5. *Facing.*

A veneer of concrete on the exposed face of a concrete unit; usually added for the purpose of improving the appearance of the unit.

6. *Faced Concrete Building Unit.*

A concrete unit having a veneer of concrete on the exposed face or faces.

Report of Committee P-5, on Fire Resistance of Concrete Building Units.

Committee P-5, on Fire Resistance of Concrete Building Units, was authorized by the Board of Direction in 1921, and at the annual convention, 1922, presented a report recommending that a series of fire tests on walls of concrete block be carried out, providing the necessary funds could be raised. This report was approved by the Board of Direction and the committee was accordingly authorized to raise the funds for carrying out this program and to proceed with the tests as soon as the required amount had been secured.

Purpose of Tests.—The purpose of this test as stated in original report is to determine the fire resistance value of concrete block and to ascertain what standard methods of mixing, which commonly used aggregates and which of the typical shapes of block produce the most satisfactory block judging from the fire resistance standpoint. It is not intended that definite ratings be assigned to the varieties of block submitted for test, but it is expected that sufficient data will be obatined from these tests to determine fire resistance values of concrete block, brick and tile relative to other building materials and simplify the task of assigning fair ratings to the products of individual manufacturers.

Test Program.—Certain minor revisions were made in the program by the committee before starting the tests; the corrected program covering the work done to date is given in Appendix A.

An active canvass was made among concrete block producers and manufacturers of concrete block machinery, dealers in aggregates and others interested with the result that a total of \$2,620 was collected by the Concrete Products Association, \$215 by the American Concrete Institute and the Portland Cement Association agreed to pay \$2,500 of the cost of the tests provided the other funds had been raised. The Concrete Institute voted \$500 giving a total of \$5,835 available for these tests.

In addition to this the Hilker Supply Co., of Granite City, Ill., agreed to furnish without charge labor and use of their plant for making the three-core block; Stainfield and Nichols Co., of Joliet, Ill., furnished similar labor and plant for the two-core block, the Prairie Concrete Products Co. at Prairie du Chien, Wis., similar labor and use of plant for making light weight tile.

The Elgin sand and gravel were donated by the Chicago Gravel Co., the slag by Illinois Improvement and Ballast Company. The tests for compression, absorption, freezing, thawing, etc., are made without charge by the Structural Materials Research Laboratory of the Lewis Institute, Chicago.

Manufacture of Block.—Accordingly, block for the six panels of oval core block were made Oct. 20, 21 and 22, 1922, at Granite City, Ill. Block for panel B (square cored block) were made at Joliet, Ill., Dec. 15,

1922, and block for panel D, light weight tile, were made at Prairie du Chien, Wis., Jan. 16, 1923.

The specimens were manufactured under the direct supervision of E. W. Dienhart, of the Portland Cement Association, representing the chairman of the committee; M. J. O'Brien, of The Underwriters' Laboratories, Chicago, and Stanton Walker, of the Structural Materials Research Laboratory, Lewis Institute, Chicago, assisted in the manufacture of the block.

The physical tests were carried out at the Structural Materials Research Laboratory, Lewis Institute, Chicago, under the supervision of Stanton Walker, Associate Engineer.

Construction of Panels.—Three panel frames of furnace No. 2 were placed at our disposal by the Underwriters' Laboratories and Panels A, G and H were installed Nov. 26, 27 and 28, 1922, in the movable walls of Furnace No. 2 at the Underwriters' Laboratories, Chicago, and panel B was installed Jan. 7, 1923.

RESULTS.

Each panel was completed in about eight hours. All blocks were laid with cells vertical and with joints broken, only full-size and half-size blocks being used.

The blocks were laid in one to three cement mortar with an addition of 10 per cent by weight of hydrated lime.

Mortar was first mixed three times dry and then thoroughly mixed wet. Each batch consisted of the following:

3 pails Lake Sand (27 lb. each)	81 lb.
1 pail Cement (30 lb.)	30 lb.
3 lb. Hydrated Lime	3 lb.
1 pail Water	24 lb.

The batches were of a sloppy consistency, but was necessary due to the dryness of the blocks which were not dampened before installing same in position.

In laying the blocks no mortar was applied to the webs. Joints which were apparently not well formed were troweled smooth. No difficulty was experienced in handling and setting the blocks, using the tools and the methods originally employed by bricklayers.

Fire Test Panels H, G and A.—The first three panels to be tested were "H," "G" and "A." They were stored inside the building at ordinary room temperature for 28 days for mortar to harden and were tested Dec. 27, 29, and 28, 1922.

Underwriters' Laboratories' standard test equipment was used. The exposed face of the panel was subjected to standardized fire conditions in which the temperatures rise rapidly to 1500 deg. F. during the first 30 min. to approximately 1700 deg. F. in 1 hr. and continue to rise

gradually until the end of the test in accordance with the standard time temperature curve shown in Fig. 5.

The test was continued 5 hr. after which the fire was extinguished and the test panel immediately drawn away from the furnace and allowed to cool.

TABLE I

Aggregate		Source	Shipper	Our Lot No.
No.	Kind			
1	Calcareous Sand	Elgin, Ill.	Chicago Gravel Company, Chicago	6417
2	Calcareous Pebbles	Elgin, Ill.	Chicago Gravel Company, Chicago	6416
3	Silicious Sand	Meremac River, Mo.	Hilker Supply Co., Granite City, Ill.	6414
4	Silicious Pebbles	Meremac River, Mo.	Hilker Supply Co., Granite City, Ill	6412
5	Crushed Blast Furnace Slag Screenings	Chicago, Ill.	Illinois Improvement and Ballast Company, Chicago	6420
6	Crushed Blast Furnace Slag	Chicago, Ill.	Illinois Improvement and Ballast Company, Chicago	6418
7	Crushed Limestone Screenings		Hilker Supply Co., Granite City, Ill.	6413
8	Cinders		Hilker Supply Co., Granite City, Ill.	6411
	Cement	Joliet, Ill.	Stainfield Nichols Concrete Co	6485

The log of the tests is given in Table II, p. 353.

RESULTS OF FIRE ENDURANCE TEST, PANEL H.

Observation During Test, Exposed Face.—The fire was semi-luminous during the first part of the test, but was luminous during the latter part. The panel showed color in patches at 15 min., the patches increasing in size and brightness until the end of the test, when the exposed face was uniformly bright red. No spalling and no cracking was noted during the test except the section of the panel in which the slag blocks (HH) were employed which began to split slightly at 95 min. and small fused deposits appeared on the exposed face of these blocks at 120 min. showing no apparent increase during the remainder of the test.

The panel bulged slightly and uniformly toward the fire, the maximum bulging on the vertical center line at the end of the test being $1\frac{3}{16}$ in. at 95 min., decreasing to ½ in. at 290 min.

Observation During Test, Unexposed Face.—At 11 min. a crack started at the top of the panel between the third and fourth block from the north side and continued to the bottom of section HH straight downward, splitting every other block and passing between the joints of the block in alternate courses. At 12 min. this crack continued to the bottom of Section H-4 stepping southward and down along the joints between the blocks. At 15 min. a crack appeared in Section HH starting at the bottom of the section just north of the vertical crack and stepping up and northward to the top of the section and north side of the panel. At the same time a crack appeared at section H-4 starting at the lower section of HH between the first and second cracks mentioned above and running straight down for three courses and then stepping southward to the bottom of the section and edge of the panel. At 22 min. it was noted that all the cracks

were increasing in width. At 2 hr. the cracks apparently were neither opening nor closing. At 2 hr. 30 min. it was quite evident that the width

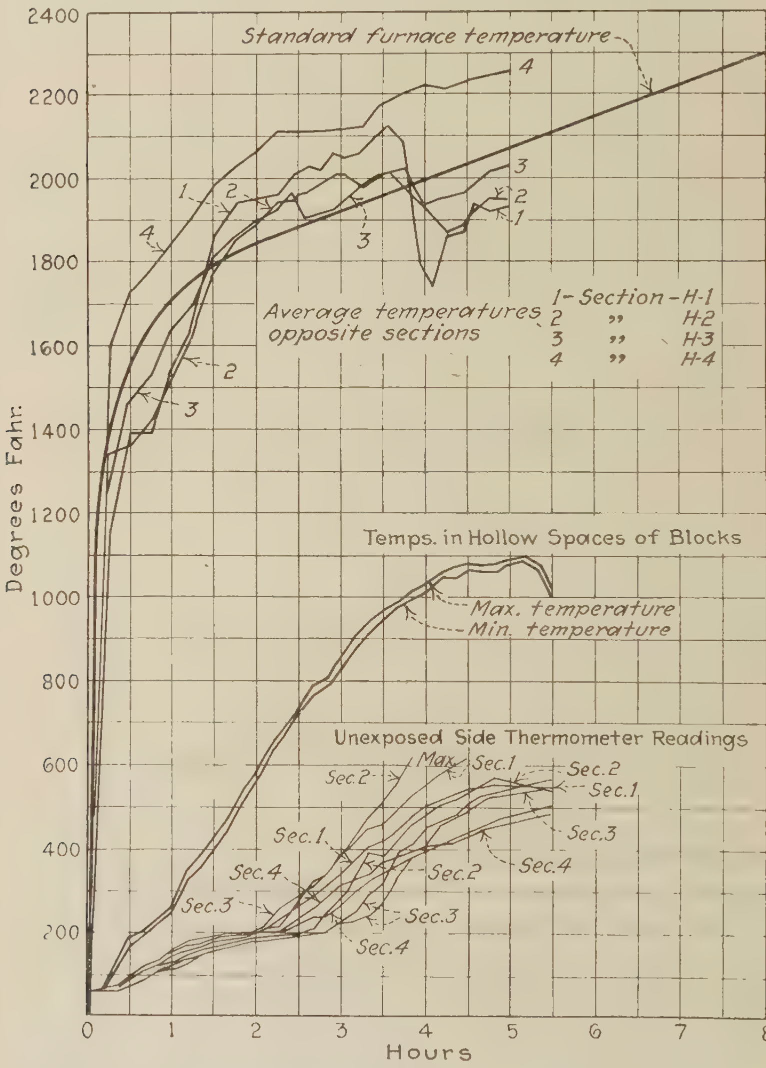

FIG. 1.—TIME-TEMPERATURE CURVE PANEL H.

of the cracks was decreasing. The width of the cracks apparently decreased until the end of the test when they were hardly visible.

Passage of steam was noted along the north and top sides and near No. 5 thermocouple at 14 min., and also through the vertical crack near

thermometer No. 4. At 20 min. some passage of steam was noted through the crack at the lower north corner. At 28 min. the volume of steam

FIG. 2.—PANEL H. UNEXPOSED FACE BEFORE TEST, SHOWING APPARATUS READY BEFORE TEST.

through the crack and around the panel was increasing. At 33 min. the mortar joints of section H-1 appeared to be wet. At 47 min. removal of the corks indicated that there was a slight steam pressure inside the

blocks. At 60 min. the volume of steam through the cracks and around the edge of the panel was apparently constant. At 61 min. the mortar joints near section H-4 appeared to be wet. At 1 hr. 5 min. the volume of steam seemed to be slightly decreasing. At 1 hr. 35 min. practically no steam came from the face of the panel, but a little still continued to pass around it. This passage of steam around the panel stopped.

There was no passage of flame through, or around the panel. At 2 hr. 15 min. the test fire could be seen through the vertical crack of section H-2. This test flame could be observed at this point until the end of the test. As the width of the crack narrowed toward the end of the test, observation of the test flames became more and more difficult.

There was no spalling or dislodgments on the unexposed face of the panel. The temperatures on the unexposed face and in the air cells of the blocks are indicated by the time temperature curves.

The curve shows a fairly uniform rise of 100 degrees on the unexposed faces in the first hour, followed by a further 50 degrees in the second hour. After this the temperature rise was more rapid on the unexposed face and varied with the different aggregates.

The temperatures on the unexposed face and in the cells are shown in Fig. 1.

After 2 hours the temperature was fairly uniform at 200 deg., but at 2 hours 40 minutes the cinder block showed 300 deg., while the limestone and slag blocks remained at 200 deg., and the siliceous gravel showed 275 deg. Steam ceased to come through the sample soon after reaching 200 deg.

Three hundred degrees is the point at which underwriters regard the insulating properties of a wall to have disappeared. As it nearly approaches the charring point of lumber; this point was reached by the siliceous aggregate after 2 hours and 45 minutes; by the limestone block at 3 hours and 15 minutes; by the slag block at 3 hours and 30 minutes and by the cinder block at 2 hours and 40 minutes, after this the temperature rise was more rapid as shown by the curve on Fig. 1.

It will be noted, however, that the furnace temperatures at the 3 hour period were from 100 to 200 deg. above the standard curve, and the exposed face of the limestone block was subjected to about 200 deg. greater heat on the exposed face than the slag and 100 deg. more than cinders at this point.

It was noticed that the brickwork around the panel had suffered considerably in the fire, some of the brick having melted and a large part of the brick filler above the lintel was loose and fell after a few bricks had been removed.

FIRE ENDURANCE TEST PANEL G.

Observation During Test, Exposed Face.—The distribution of the fire was rather irregular and semi-luminous during the first 15 min., becoming more evenly distributed and more luminous at 20 min. and continuing

so until the end of the test. The sample showed signs of color at 10 min. in the lower north corner, increasing in area until 60 min. when the entire

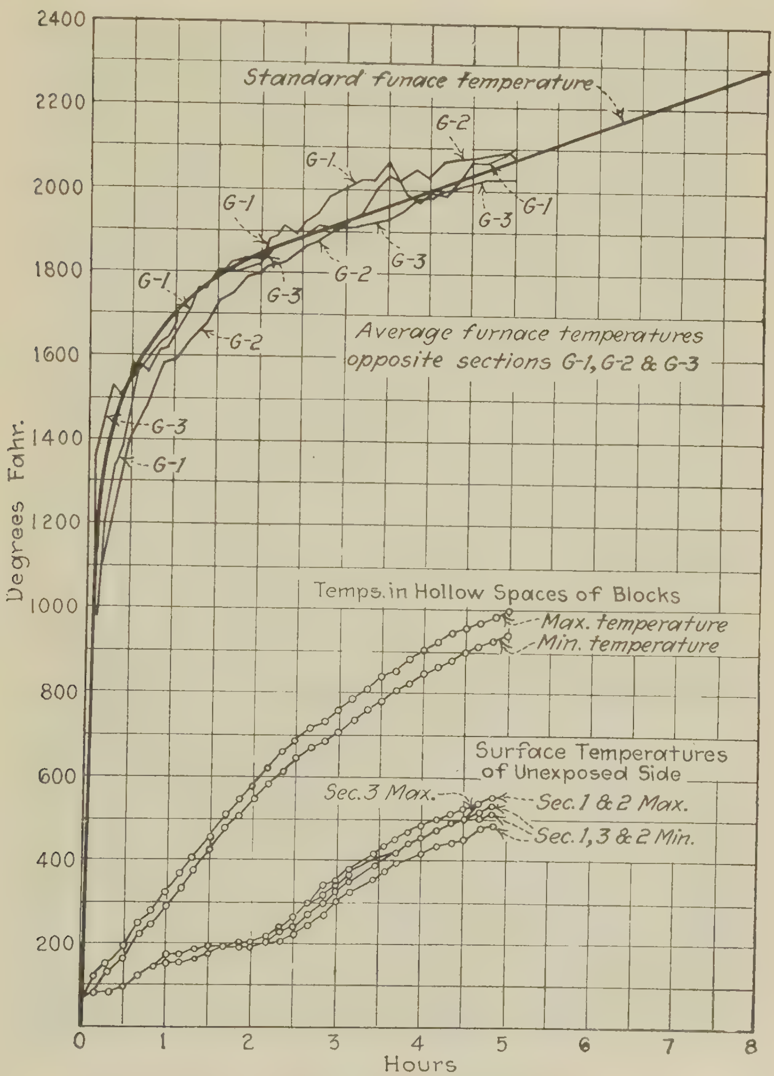

FIG. 3.—TIME-TEMPERATURE CURVE PANEL G.

exposed area was cherry red and at the end of the test the sample was bright red.

Temperatures in the furnace chamber are shown by Fig. 3.

No spalling, cracking, or separations were noted during the test on the exposed face.

FIG. 4.—PANEL G. EXPOSED FACE BEFORE FIRE ENDURANCE TEST.

The sample was withdrawn from the furnace at 5 hrs. and allowed to assume normal inside temperatures.

Observation During Test, Unexposed Face.—Before the test it was noted that the panel had several small cracks in the mortar joints. At

13 min. it was observed that these cracks were opening. At 20 min. several cracks appeared in the bottom section. At 1 hr. cracks began to

FIG. 5.—EXPOSED FACE AFTER ENDURANCE TEST OF FIVE HOURS.

open at the joints between the test sample and the panel at the sides and bottom. At 1 hour 40 minutes a crack at the south side of the test sample was approximately ¼ in. in width; the one at the north side, and the

one at the bottom of the sample was approximately ¼ in. in width. At 2 hours 30 minutes it was noted that the width of the cracks slightly

FIG. 6.—PANEL G. UNEXPOSED FACE OF PANEL G AFTER ENDURANCE TEST OF FIVE HOURS.

decreased. This was noted to continue during the remainder of the test.

At 20 minutes passage of steam was noted at the cracks and at the sides of the panel. At 30 minutes moisture was noted coming through

at the mortar joints. At about 1 hour the volume of the steam coming through the cracks was about constant. From this point it apparently

FIG. 7.—PANEL G. IMPACT TEST. BEAMS SUPPORTED IN POSITION BEFORE TEST.

decreased in volume until two hours the only steam that appeared on the unexposed face came through the crack at the south side of the panel. At 2 hours 30 minutes there was no apparent passage of steam.

At no time during the test was there passage of flame through or around the test sample. At 1 hour 20 minutes the furnace chamber fire

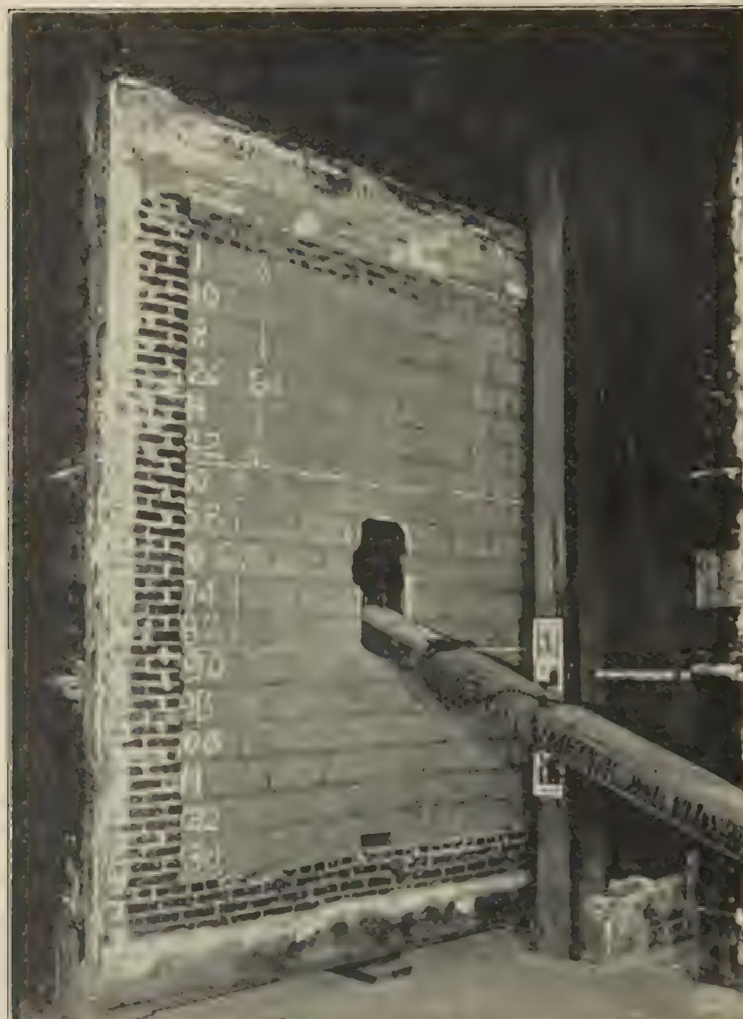

FIG. 8.—PANEL G. IMPACT TEST. EXPOSED FACE OF WALL AFTER FIRST BLOW.

could be seen through the vertical mortar joint one block from the south side of the panel and six courses across and up from the bottom.

There was no spalling or dislodgment of any of the materials on the unexposed face of the panel during the test.

Condition of samples are shown in Fig. 4-9.

The unexposed face temperatures rose to 200 deg. in 1½ hours, although the furnace temperatures ran close to the standard curve. The

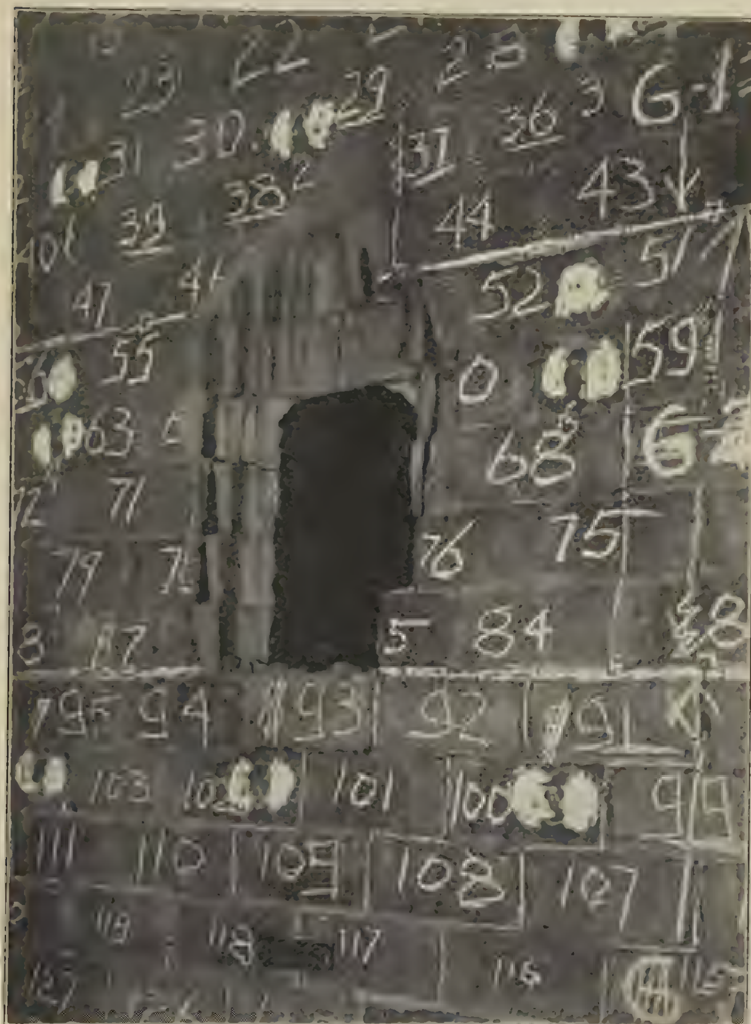

FIG. 9.—PANEL G. IMPACT TEST. UNEXPOSED FACE AFTER FIRST BLOW.

unexposed temperatures remained at 200 deg. until 2 hours 15 minutes, after which they commenced to rise rapidly, indicating that all moisture had been driven off. The 300 deg. point was reached at about 2 hours 45 minutes, and the maximum at end of 5 hours was 550 deg.

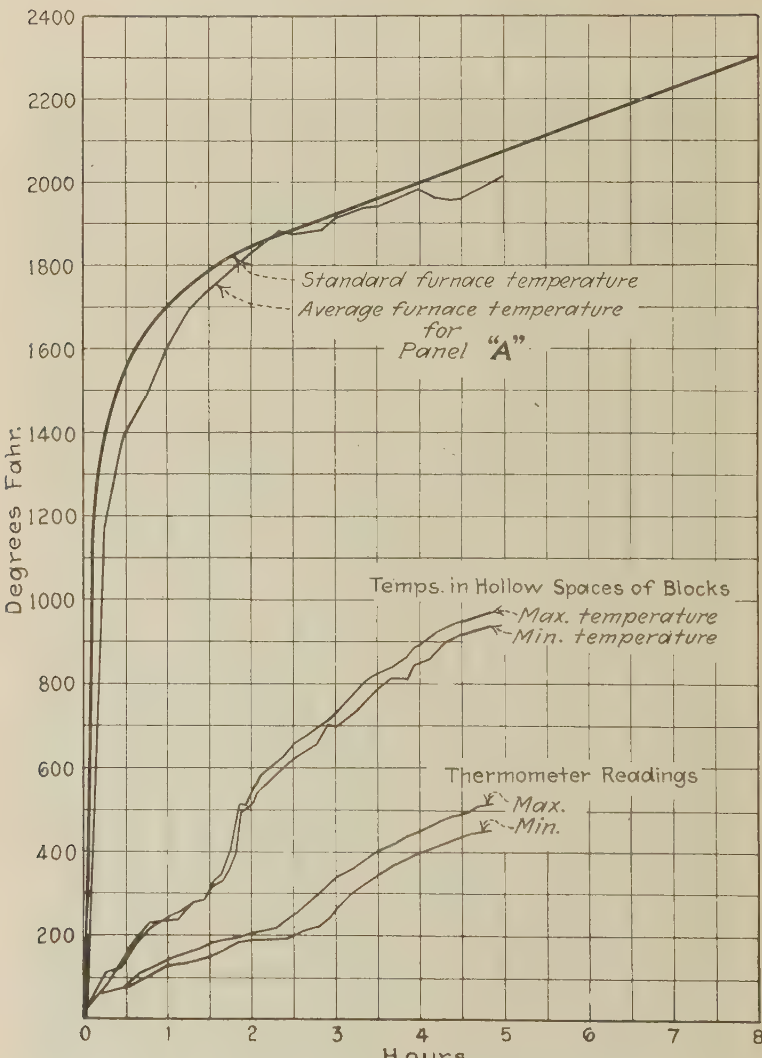

FIG. 10.—TIME-TEMPERATURE CURVE PANEL A.

Deflections.—The maximum deflection in the upper middle of Section G-1 was 2 in. toward the fire at 225 min. which decreased to 1¾ in. at 290 min.

The maximum deflection toward the fire at the center of the panel Section G-2 was 2$\frac{15}{16}$ in. at 170 min. which decreased to 2⅝ in. at 290 min.

The maximum deflection in the middle of the lower section G-3 was $1\frac{7}{16}$ in. at 140 min. which decreased to $1\frac{1}{4}$ in. at 290 min.

FIG. 11.—PANEL A. EXPOSED FACE BEFORE FIRE ENDURANCE TEST.

IMPACT TEST PANEL G.

The test was made upon the Panel G that had already been subjected to the Fire Endurance Test, the sample having been undisturbed for six days after that test.

The movable wall carrying the test panel was blocked so that it could not swing, and was twice subjected to the impact of a steel and concrete member 16 ft. 6 in. long, mounted vertically on a hinge base, and designed so that when released it would swing in a vertical arc with its hinged base as a center, the upper end of the member striking the test panel at about its middle point. Fig. 7 illustrates the appearance of the upper portion of the swinging member and indicates its position at the moment of contact with the panel. The weight of the member was approximately 2500 lb. Its original distance from the panel was approximately 14 ft. The general effect of the test was intended to be representative of the effect of structural members falling against a wall during or after a fire.

Results.—The effect of the first impact is shown in Fig. 8 and 9. The end of the swinging member struck the panel midway of Course 50. It ruptured blocks locally so that a through opening was formed about 28 in. high and with width equal to the width of the swinging member, or 15 in. In the immediate neighborhood of the through opening other blocks were damaged as shown in Fig. 8 and 9. No other blocks were affected and the stability of the wall as a whole was apparently not impaired.

The second impact enlarged the damaged portions so that on the exposed face it involved a total of 6 courses in height and 16 to 18 in. in width, the damaged portion on the unexposed face being 9 courses high and about 18 in. wide. No damage was apparent in blocks not immediately adjacent to the main ruptured portion and the stability of the wall as a whole was apparently not impaired.

FIRE AND WATER STREAM TEST—PANEL A.

The test was made on Panel A described under the heading "Installation Tests." It was 35 days old. The appearance before the test is illustrated by Fig. 11.

The sample was subjected to the standard fire test for 5 hr.; it was then drawn away from the furnace and a 2½ in. hose stream from a 1⅛ in. nozzle was applied to the heated face for 5 min. The stream was applied from a position 20 ft. distant and opposite the center of the panel. It was directed first at the center and then at all parts of the exposed face, changes in the direction of the stream being made slowly. The pressure at the base of the nozzle was 50 lb.

During exposure to fire the usual observations were made. After the application of the hose stream observations were made to determine the condition of the materials resulting from the impact, pressure and rapid cooling due to the stream.

Observation During Test, Exposed Face.—The fire in the furnace chamber was semi-luminous during the first 10 min. becoming more luminous at 15 min. and increased in luminosity until the end of the test. The sample showed signs of color at 15 min. increasing in area and intensity until 75 min. when the sample was a cherry red all over. The

intensity in color increased during the latter part of the test and the sample was bright red when withdrawn from the furnace chamber.

Temperatures during test are shown by Fig. 10.

No apparent cracking, or spalling was noted during the test.

The maximum deflection toward the fire at the middle of the sample was 2⅜ in. at 105 min. which decreased to 2⅛ in. at 290 min.

The hose stream eroded away the exposed surface to a depth varying from ½ to 1⅛ in. averaged about ⅞ in. No openings were formed through the panel although the hose stream washed away the mortar joints in a few places.

Observation During Test, Unexposed Face.—On the unexposed side of panel cracks occurred at the mortar joints at 1 min. and developed rapidly during the first 5 min. A vertical crack running continuously through 6 courses of blocks developed at 4 min. near the vertical center line of panel extending downward from the horizontal center line. At the end of 10 min. period practically all mortar joints were cracked and in addition a long vertical crack, about two-thirds of the height of wall, developed in the north quarter of the test wall and extended about equally above and below the horizontal center line. Further opening of cracks in masonry joints occurred slowly all over the wall up to the 40 min. period. At 45 min. cracks in mortar joints opened up considerably in lower south corner of panel and at 50 min. a similar opening occurred at lower north corner, joints in other portions of panel remaining unchanged until 180 min. period when they started to slowly close. At 120 min. a crack developed in lower mortar joint in lower south corner of panel through which fire was visible until end of test. At 150 min. another crack opened up near south edge and below horizontal center line of panel sufficiently so that fire could be seen until end of test. At 165 min. a crack about 1/10 in. wide developed in mortar joint between first and second courses of blocks at bottom of panel extending horizontally across entire width of panel. At 180 min. flame was visible in this crack at a point near the north edge of panel and could be seen to end of test. Little further change occurred during remainder of test except slow closing of mortar joints in upper half of panel, but all these cracks were easily visible at end of test.

At 35 min. steam began to issue from mortar joints and damp spots formed, especially at upper half of pane. The amount and extent of steam increased somewhat until the 70 min. period and then remained practically constant to end of test.

Temperatures on unexposed face were almost identical with Panel G. The hose stream had no apparent effect on the unexposed face of the panel.

Observations After Fire and Hose Stream Test.—About ⅞ in. of the exposed face of the blocks were washed away by the hose stream leaving the remainder of the shell with very little strength due to the dehydration and calcination of the aggregates. About 21 per cent of the blocks were cracked vertically through the middle of the exposed and unexposed shells.

About 12 per cent had only the exposed middle shell cracked, and about 2 per cent of the blocks had the end webs cracked, and about 1 per cent with cracks noted at other points in the block. The damage to the blocks was more marked in the lower half of the panel than the upper. The webs and shells were generally cracked in the bottom row of block.

The brickwork around Panel A was cracked and broken, and when the hose stream was applied considerable spalling took place.

CONDITION OF PANELS AFTER TEST.

Panel H.—Blocks in Panel H were removed from the frame December 28th.

The top five courses of block of siliceous gravel were removed first.

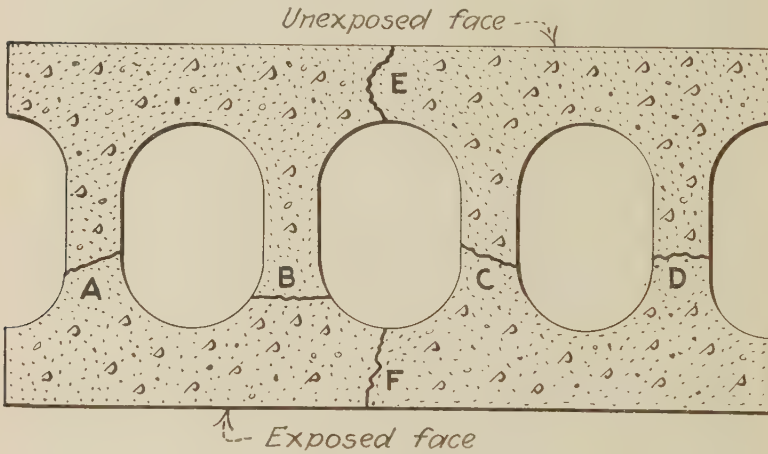

FIG. 12.—CRACKS IN TILE IN PANEL H.

The majority of these block were cracked through the webs and several were also cracked through front face or from front to back. Of 40 block in this section only 7 were taken out whole.

The blocks H-1 of the upper five course in Panel H siliceous gravel aggregate appeared to be generally shot to pieces. When not fallen apart from handling for removal, they required very careful further handling. The two specimens tested for compression after fire, however, tested 700 lb. per sq. in. Dehydration seemed generally back from exposed face from two to three inches. One block had some mortar adhering and weighed 45 lb. when removed from wall. A reserved sample of this same block not tested by fire weighed 43 lb., this data would give no loss in weight from dehydration. At fractured points the coarse aggregate showed the characteristic red color of Merramec river gravel. In general no fracturing of aggregate was observed in face of fractures in block. The pebbles remained whole for at least 97 per cent of pebbles observed in the fractured areas.

It may be observed that the two lower courses of this upper lot of five seemed to be in somewhat better shape than blocks in the three upper courses of the five. This difference while observed is not to be regarded as materially significant as all of the tile are in poor condition, requiring delicate handling and showering dust when purposely broken by dropping on a concrete floor. Contrary to expectation there was no evidence of splitting of aggregate due to water of crystallization turning to steam. The sketch, Fig. 12, is representative of the condition of the tile in so far as cracks apply.

A, B, C and D always located a little above the crest of oval cracks, usually all four. Occasionally end cracks did not appear. A few times center cracks did not appear. Frack F frequent. Crack E very frequent. Crack F usually during progress of fire test incurred probably in third five minutes. Cracks A, B, C and D appear to mark limit depth of severe dehydration.

The next four courses were of cinder aggregate mixed with Elgin sand and portland cement 5 to 1. The exposed face after fire shower characteristic greenish color. Dehydration had taken place for a depth of 1½ to 2½ in. This surface dehydration makes the surface soft or "punky" for about ¾ in. in depth.

The cinder block were otherwise in fair condition and much superior to the block above made with siliceous gravel aggregate. Shallow cracks were observed; in many of the webs usually about 2 in. back from the exposed face—a majority of the block though cracked were whole when removed from the panel.

Block in the line of the main vertical cracks were cracked from front to back.

The next four courses in Panel H were of crushed air cooled slag aggregate with Elgin sand and portland cement 5 to 1. About half of these block were removed from the fire in good condition—characteristic web cracks observed in many of the block and front to back cracks observed in the line of the main cracks in the whole panel.

The lowest four courses in Panel H had crushed limestone aggregate with Elgin sand mix 5 to 1.

In general block with coarse aggregate of limestone showed dehydration and calcination on the face exposed to fire for a depth of ¾ to 1¼ in., otherwise dehydration only and this only of moisture in suspense. On broken surface the fracture of pieces of aggregate observed to a greater extent than with other blocks composing Panel H.

Speaking of all four aggregates the characteristic condition upon removal is as indicated in the sketch Fig. 20.

Crack A is more frequent than B, C or D. Crack D more frequent than B, or C. Cracks A-D 2 or more observed more frequently than at F. Cracks very common. Crack E not observed during progress of fire test no doubt because of reflections from flame and extreme angle of view.

The blocks did not show same resistance to abuse in handling as

before the fire test. Those with siliceous aggregate noticeably the poorest in this respect, cinders the best of the four in this respect, with limestone next, and slag practically as good as limestone. In every case the fractured surfaces were dusty. Dehydration was probably deepest in the case of the cinder block. Particles of coal comprising the aggregate burned to ashes to a depth of about ½ in. A greater depth of coal remained unburned. In the case of the block with limestone aggregate complete calcination of the aggregate to quick lime took place for a depth of about ¼ in.

The 5-hr. endurance period drove all free moisture from all samples. The extent to which the coarse and fine aggregate or cement binder is materially injured by temperatures rise after moisture disappears remains to be determined. The possibility of partial or complete recovery to original condition from absorption of moisture from the atmosphere remains to be investigated.

Panel G.—The outer shell on these blocks was apparently hard and intact, but then immediately behind this outer crust the block was calcined from ½ to ¾ in. and sections of this calcined area fell away during removal from panel. Blocks that were cracked in several places could be removed from wall and handled without breaking and only under very favorable light conditions and close observation was it possible to detect the cracks.

Very little difference could be observed in the fire resistance of block of different mixes 1 : 6, 1 : 4 and 1 : 3.

In the top five courses (1 : 6 block) characteristic web cracks were formed but most of the block were taken out whole. The lower two sections of the panel (1 : 4 and 1 : 3 mixes) were badly cracked in all directions. These two panels bore the full brunt of the impact test and it is probable that the excessive cracking of these block as compared with the 1 : 6 block above or the 1 : 5 block in Panel A is due to this factor.

Panel A. 1 : 5 Mix Calcareous Gravel.—About 21 per cent of the block in this panel were cracked vertically through the middle of the exposed and unexposed shells—12 per cent had the middle shell only cracked and about 2 per cent had end webs cracked—one per cent had cracks at other points.

About ⅞ in. was washed from the exposed face by the hose stream leaving very little strength in the remaining of the exposed shell due to dehydration. The webs and unexposed faces remained sound and there was probably enough structural stability remaining in the panel to carry the load usually allowed by building codes.

Compression Tests and After Fire Test.—The series of compression tests to be made on block removed from the panels after the fire test was not complete when this report was written. Siliceous aggregate block tested 3 days after the fire showed a loss in strength of 30 per cent, the cinder concrete block lost 41½ per cent, the slag concrete lost 47½ per cent and the limestone 32 per cent.

Further tests made one week later showed that the block had regained

a little of the strength lost. The cinder block regained 3 per cent of its original strength in 7 days and 9 per cent in 10 days; the slag block 7 per cent in 10 days and the limestone block 27 per cent in 7 days and 32 per cent in 10 days. There were not enough siliceous block left to make further tests.

All the fire tested blocks failed first on the fire side when tested instead of the typical pyramid failure.

GENERAL NOTES.

The through cracking on the faces of the block is probably due to the tension set up by the bulging of the panels toward the fire. The question has been raised whether the method of manufacture on other machines having different methods of tamping or removal would give better results.

If Panel B, the next one to be tested, shows a difference in through cracking due to the difference in the action of the machine tampers, the Committee may wish to change the program using more block made on stripper or pressure machines after observing the results of the tests on this panel.

Although it is probable that the fire resistance of concrete block walls is adequate for ordinary fire hazards, it cannot be relied upon to come out unscathed from a fire which approaches the severity of the tests carried on at the Laboratory. Such conditions are rare in actual fires, and judging from the common standard brick work around the panels which was damaged more extensively than the block, it is doubtful if any kind of 8 in. brick or 8 in. block wall would gain a perfect rating in such a test.

From the five-hour test it was not possible to determine at what time or temperature serious injury is caused and as this information is of primary importance to the concrete products industry and to the fire insurance business, the committee believes that the original program should be modified in order to determine the point at which loss of stability or structural strength through web cracking or dehydration takes place and whether form or method of manufacture are more important than composition.

In order to do this, it will be necessary to substitute for some of the panels now arranged in the program other panels—duplicates of those already tested which shall be tested for shorter periods.

There are three principal ways for a wall assembly to fail from the fire retardant point of view. One of these has not so far appeared. This is the actual passage of flame through openings created by fire conditions. The second critical point is breakdown of heat insulating properties which is marked by a temperature of 300 deg. F. on the unexposed face. For the three panels tested this point appears to be reached at approximately 2 hours 45 minutes.

The third critical point is loss of stability or load bearing value.

Expansion forces in the exposed face manifest themselves in two ways, one by through cracks which appear inside of the 15-min. period in the case of the three panels thus far tested. The other way is by fracture of webs. The time when fracture occurs is not known. It may be practically synchronous with the through cracks or it may be very much later. Through cracks, of moderate extent, probably need not be regarded as affecting the load boaring capacity of the wall to an unfavorable extent. But if the cracking of webs marks the failure point as to load bearing capacity there is no justification in contemplating a favorable classification beyond the time period when web cracking is common. It may be urged, however, that the ease with which such walls may be strengthened by filling air cells with new concrete after a fire, with or without reinforcement, minimizes the seriousness of this defect.

It accordingly remains to determine, if possible, when web cracking occurs; the future program should be carried through with this point most distinctly in mind as well as with the original point of determining, if possible, effect of various variables in the construction. The variables which remain for investigation will probably manifest their effects, if any, quite as clearly with an abbreviated fire test period and the committee accordingly proposes to revise their program so as to determine the point of time at which failure of typical block occurs—having in mind method of manufacture in various machines, variation in aggregates, etc., so far differences of mix have not revealed any difference in fire resistance and it is doubtful if differences in method of curing would show any marked variation in fire resistance.

As in the majority of cases concrete block walls are covered with portland cement stucco, it seems also desirable to determine what additional degree of fire resistance is afforded by this stucco and whether the failure of portland cement stucco as a protection to concrete block is caused by unequal expansion causing the stucco to fall off quickly or whether it remains as a protection until calcination of the stucco coat has taken place. It will not be difficult to cover one-half of any panel with stucco, in order to observe this, and accordingly Panel B, now awaiting test, has been so covered on half the exposed face.

The committee feels confident that this series of tests will reveal much important and valuable data. Much has already been learned regarding the behavior of concrete block and fires and the experience gained will be a guide to the committee in arranging further tests.

The remarkable value of concrete block as a fire retardant has been established by the tests already carried out. They are convincing evidences that concrete block is fully the equal of any other material commonly used for wall construction.

The committee desires to express its grateful thanks and acknowledgments to those who have so liberally contributed in materials, money, time and use of facilities.

Table II. Log of Tests.

Panel No	Date Made: Fire Test	Date Made: Strength Test on Fired Block	Mix	Consistency	Method of Curing	Kind of Aggregate	Compressive Strength of Block, lb. per sq. in.: Before Fire Test, Gross Area	Before Fire Test, Net Area	After Fire Test, Gross Area	After Fire Test, Net Area	Points of Failure on Block Subjected to Fire Test
H-1	12-27-22	12-30-22	1 : 5	Wet	Steam	Silicious	1220	2060	730	1230	Web and fired side
						sand and	1000	1700	680	1150	Web and fired side
						pebbles	990	1670			
							920	1560	Av. 700	1190	
							920	1560			
							Av. 1010	1710			
H-2	12-27-22	12-30-22	1 : 5	Wet	Steam	Calcareous	960	1620	580	980	Web and fired side
						sand and	920	1550	530	900	End web
						boiler	980	1650	600	1020	Fired side
		1-6-23				cinders	950	1610			
							1020	1730	Av. 570	970	
							Av. 970	1630	580	970	Fired side
									600	1010	End web
									630	1060	Total failure
									Av. 600	1010	
		1-9-23							720	1210	Fired side
									560	950	Fired side
									690	1170	Fired side
									Av. 660	1110	
H-H	12-27-22	12-30-22	1 : 5	Wet	Steam	Calcareous	1010	1770	530	890	Corners fired side
						sand and	990	1670	550	930	End web
		1-6-23				crushed	1040	1750			
						air-cooled	990	1670	Av. 540	910	
						slag	1100	1890			
									650	1100	Fired side
							Av. 1030	1740	630	1060	Fired side
									Av. 640	1080	
H-4	12-27-22	12-30-22	1 : 5	Wet	Steam	Calcareous	1360	2300	780	1310	Fired side
						sand and	1110	1880	810	1370	Fired side
						crushed	980	1650	610	1030	Fired side
		1-6-23				limestone	910	1530			
							980	1650	Av. 730	1240	
							Av. 1070	1800	830	1520	Fired side
									790	1340	Fired side
									690	1160	Fired side
									Av. 770	1340	
		1-9-23							980	1650	Total failure
									1110	1880	Fired side
									1280	2160	Fired side
									Av. 1120	1900	
A	12-28-22	1-19-23	1 : 5	Wet	Steam	Calcareous	1252	2121	1010	1685	Unexposed side
						sand and	1010	1710	780	1300	Fired side
						pebbles	1240	2110	1070	1785	Fired side
							1010	1708	840	1400	Fired side
							Av. 1128	1912	Av. 920	1530	
G-1	12-28-22	1-19-23	1 : 6	Wet	Steam	Calcareous	1154	1955	750	1250	Fired side
						sand and	1184	2009	700	1165	Fired side
						pebbles	1218	2062			
							1153	1956	Av. 725	1205	
							1080	1830			
							Av. 1158	1962			
G-2	12-28-22	1-19-23	1 : 4	Wet	Steam	Calcareous	1350	2284	600	1000	Unexposed side
						sand and	1820	3080	570	950	Fired side
						pebbles	1720	2924			
							1600	2720	Av. 585	865	
							Av 1622	2752			

E. W. Hilker, Messrs. Stainfield and Nichols and Geo. Lengst, who placed their plants at our disposal in the middle of a busy construction season, merit special mention. Stanton Walker's assistance has been invaluable The staff of the Underwriters' Laboratories have been untiring in their efforts. The excellent organization and equipment of these laboratories has been a big factor in running the tests through without a hitch.

The committee desires that this progress report be accepted and that it be authorized to complete its work by testing five additional panels, making such changes in the program as experience gained by it from time to time may lead them to believe will produce the most useful data. It will then be able to present a complete report before the Institute at its next annual convention.

LESLIE H. ALLEN, *Chairman*,
HARVEY WHIPPLE, *Secretary*.

Appendix A.—American Concrete Institute, Committee P-5, Fire Resistance of Concrete Building Units, Program of Tests—Revised to January 12, 1923.

In all of the tests, unless otherwise noted, the block tested is to be of the three oval core type, 8 x 8 x 16 in., to be of 1: 5 mix, to be of a semi-dry mix having a consistency wet as possible, tamped with automatic tampers and to be hardened in the steam room. Except as otherwise speci-

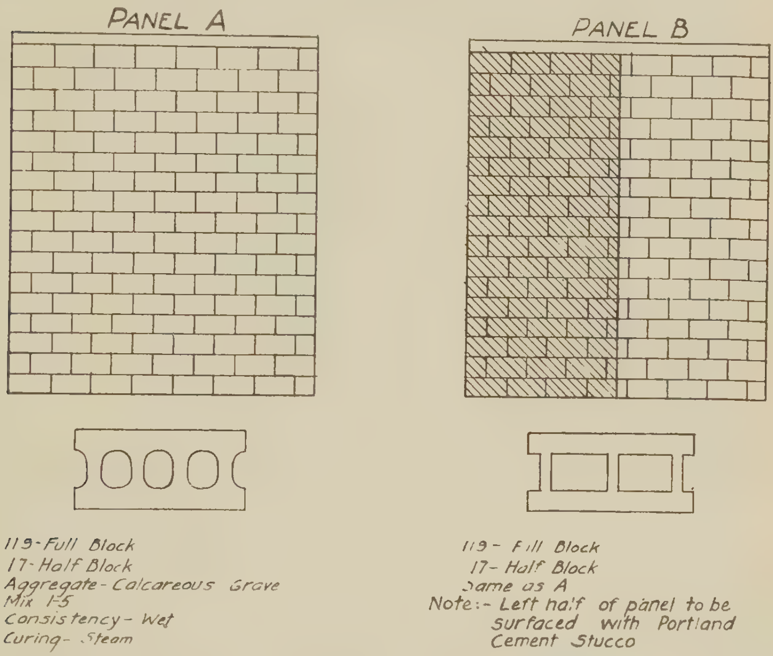

FIG. 13.—DETAILS OF PANELS A AND B.

fied, the aggregate is to be Elgin (calcareous) sand and pebbles grading 0 to ⅜-in.

Panels will be tested in Furnace No. 2. Panels to be mounted in a steel frame providing exposed face of panel approximately 10 x 11 ft., containing 17 courses of block, each course containing approximately 7½ block.

The mortar will be made of any local sand and portland cement purchased in the local market. The proportions of mortar will be one part of cement to three parts sand measured by volume. Hydrated lime not exceeding ten per cent by weight of the cement will be added.

The panels will be allowed to harden at ordinary room temperature

and a minimum of 28 days is to elapse between the completion of any panel and the date of the furnace test.

Panel A will be as above described. This panel to be tested up to time of failure, but not to exceed 5 hours, the furnace temperature to be in accordance with the standard time temperature curve. At the end of 5 hours, the panel to be withdrawn from the furnace and thereupon subjected to the standard fire hose stream test.

Panel B to have blocks with two square cores, otherwise to be similar in all respects to Panel A.

Panel C will have eight courses of block 1:8 mix and nine courses 1:7 mix. Block will be similar in all other respects to Panel A.

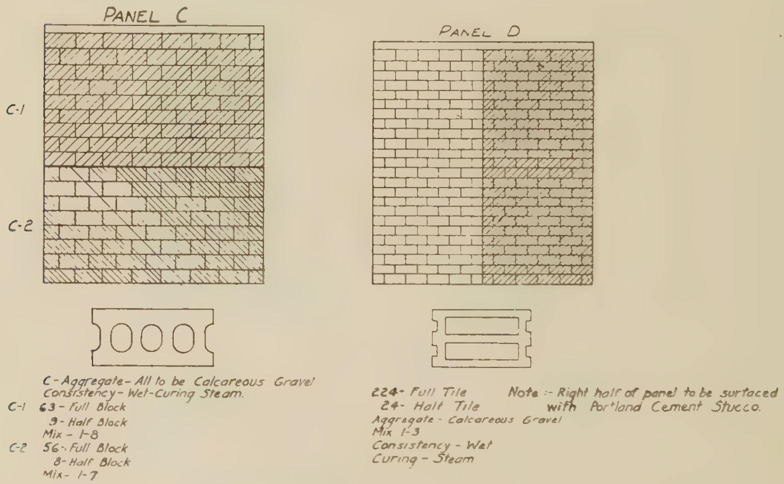

FIG. 15.—DETAILS OF PANELS C AND D.

Panel D will be built of 5 x 8 x 12 concrete building tile, mix 1:3, curing and consistency like Panel A.

Panel E will be assembled as follows: Courses 1 to 6 from the top of the panel to be filled with block of a semi-dry consistency. Courses 7-11 to be filled with block made with a damp consistency. Courses 12 to 17 to be filled with block mixed as wet as possible. All of these block to be of a 1:5 mix, to have an aggregate of Elgin sand, with 0 to ⅜-in. pebbles hardened in the steam room and to be of the three core oval type.

Panel F to be filled with block in the manner indicated for Panel E, the various details being the same except that all block has been hardened in air instead of the steam room.

Panel G is to be assembled similar to Panel E except that the three sets of courses will be filled with block representing variations in mix as follows:

Courses 1 to 6—a mix of 1 : 3
Courses 7 to 11—a mix of 1 : 4
Courses 12 to 17—a mix of 1 : 6

Aggregate consisting of Elgin sand and pebbles graded 0 to ⅜ in.; consistency wet as possible and hardened in steam room.

Panel H to be run to determine the effect of fire on different kinds of aggregates, the panel to be filled with four groups of block each in four courses. For courses 1 to 4 block shall have an aggregate of Elgin sand

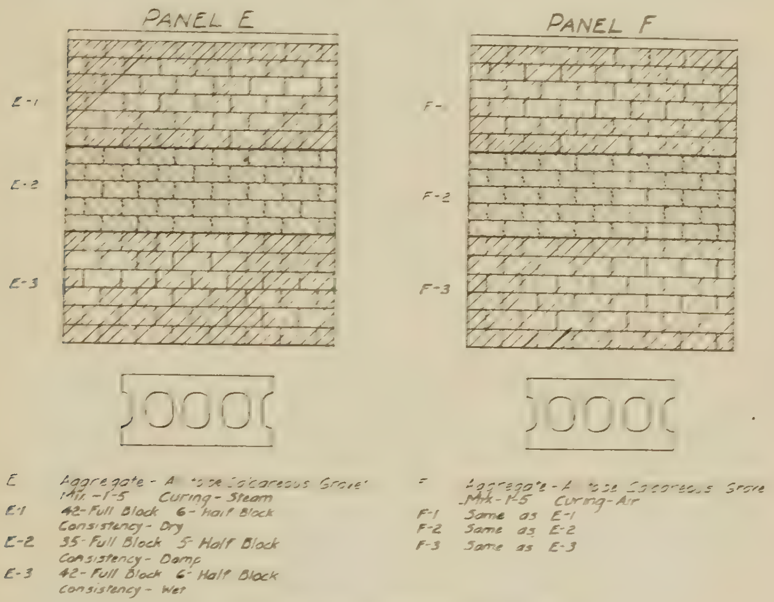

FIG. 16.—DETAILS OF PANELS E AND F.

and crushed limestone. For courses 5 to 8 block shall have an aggregate of Elgin sand and crushed air-cooled slag. For courses 9 to 12 the block shall have an aggregate of Elgin sand and cinders. For courses 13 to 17 the block shall have an aggregate of siliceous sand and siliceous gravel. (In all other tests an aggregate consisting of Elgin sand and pebbles grading 0 to ⅜-in. has been employed.) Panel H will be placed in the furnace first.

Panel B will have half the exposed face covered with portland cement stucco—in order to observe what additional fire resistance is given by stucco.

Panels B, C, D, E, F, G and H will be exposed to the standard fire conditions in accordance with the standard time temperature curve for a

minimum period of one hour and for a maximum period of 5 hours. The actual time of exposure being determined at the time of test according to observations made of the condition of the face of block exposed to fire and in accordance with the judgment of the test engineers as to the best period for discontinuing test in order to ascertain the exact relative performance.

It is not proposed to subject Panels B, C, D, E, F, G and H to the fire hose stream test.

Measurements of temperature during the test to be by thermocouple

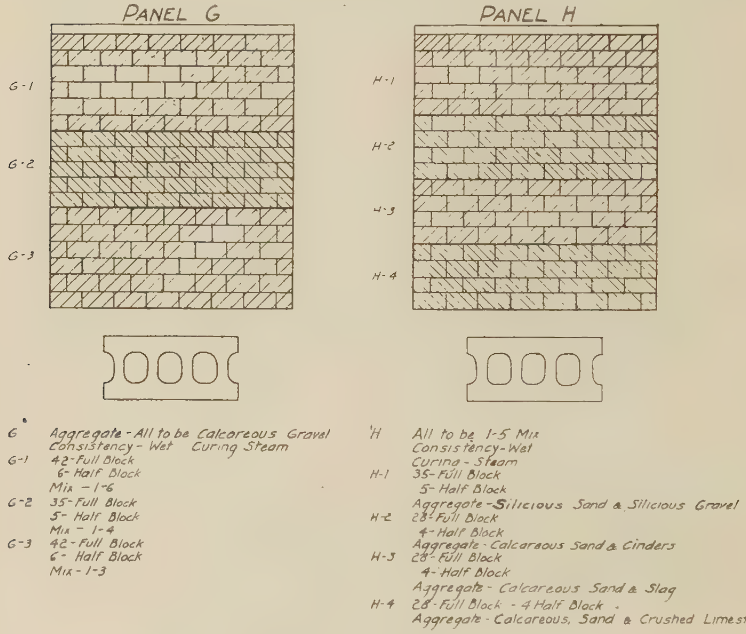

FIG. 17.—DETAILS OF PANELS G AND H.

arrangement according to usual practice of the Underwriter's Laboratories.

Physical properties of 5 representative samples representing each variation in manufacture will be determined at the Lewis Institute Laboratories in accordance with the adopted standard program of the American Concrete Institute for the test values in question, these being strength in compression, and absorption of specimens dried to constant weight.

Additional strength tests shall be made on a limited number of block representing the usual range of manufacturing practice, as follows:

1. After being subject to freezing and thawing. (The freezing and thawing test shall be conducted as follows: Alternately saturate

block in water at room temperature and expose to freezing temperature over night 5 times and test in compression; the block shall be room dried before making the strength test.)

2. In saturated condition.

3. As received in room dry condition. Representative block which have been subjected to the fire and fire hose stream tests shall be subjected to the following tests:

1. Absorption.
2. Strength.
   a. As received from fire test.
   b. After saturation and room dried.

LESLIE H. ALLEN,
Chairman Committee P-5.

Report of Committee C-1, on Contractors Plant.

Part of this report was presented verbally by Committee C-1 at the convention last year and owing to inability to get the necessary drawings prepared in time for publication, this report was omitted from the proceedings.

This report is now submitted complete by the committee as a corollary of the last published data in 1921 and is submitted in full with charts and data brought up to the fall of 1922.

All detailed figures showing the preparation of data for Plant No. 5 are attached as an outline to follow for anyone wishing to make similar curves themselves.

The report is divided for convenience into three parts:

(1) A consideration of the factors that govern the choice of wheeling or chuting equipment as a means of placing concrete.

(2) A re-study of the last published charts which were made when conditions in labor and material market were abnormal.

(3) A new set of charts similar to those published in the 1921 Proceedings but based on the more normal conditions existing at the present time in the material and labor markets.

The broad question of when chutes may and may not be used with economy is one to which contractors are giving increasing careful thought, particularly in view of the increased labor efficiency now obtainable and the lowered wage scale. At the outset of the committee's work last year it was suggested by the Board of Direction that this subject might be given the committee's almost exclusive attention, in order that some simple routine form of analysis might be developed by which the average contractor could decide for himself whether or not the use of chutes would save him money. This has been made the principal part of the report.

Conditions in the labor market have changed materially in the last two years, since the various charts were printed in the report of this committee. The present situation as regards supply and efficiency of labor is probably a much more normal condition than that which existed then and it has been decided by the committee that it would be advisable to re-plot the charts already published. The results given by the 1921 charts would only apply to a period of abnormal shortage of labor with its resulting higher rates and inefficiency of production. Information given under these conditions would tend, of course, to advise a much higher investment in plant than the present conditions would justify. This revision of the charts is especially necessary because of the importance given in this report to the choice between the placing of concrete by chutes or wheeling.

The charts have therefore been redrawn on a basis of plant equip-

ment costs for the fall of 1922 for the same layouts as in 1921. Labor rates have been reduced to $4.50 for 8 hours, as wage scales throughout the country have been generally established at new and lower levels. A few territories are still maintaining peak wages, but they are exceptions and their condition is really abnormal; the units assumed in the charts will have to be changed to correspond with the local scale where the same differs materially for that assumed above.

The new charts, with the information given in Part 3, are intended to be self-explanatory and will not require reference to last year's report.

1.—ANALYSIS OF CHUTING AND WHEELING PLANTS.

The principal problem facing a contractor in making a decision as to what kind of plant to use on a certain concrete structure is a proper conclusion as to the relative merits of placing concrete by means of wheeling or chuting. One method or the other may be obviously more suitable for a certain job and here the decision is easy to make without any chance of error, but for each job like this, there will be many pieces of work where the correct choice may only be made after a careful study has been given to all of the conditions governing the work to be done, as affecting the relative economy of one type of plant or the other.

This decision once properly made, the other details of plant layout such as location of plant or arrangements for receiving materials, may be properly determined by similar methods of analysis for either case.

Wheeling has been used in the past for almost every type of building operation. It has been favored because of the low cost of plant installation and negligible upkeep charges. Its effectiveness is limited chiefly by the distance which it may be necessary to wheel from the mixing plant. It is always theoretically possible to use enough wheelers to take away the concrete as fast as it can be mixed (barring labor shortage). The number of men required to maintain a given speed of fill, however, will increase with each addition to the distance from the hoist tower to the point of deposit of the concrete in the forms. Starting, therefore, with the lowest cost for placing concrete in front of the mixer, the labor cost per cubic yard will rise with each addition to the haul. With a chuting plant conditions are otherwise.

Chuting plants are of two general types. The self-contained type, usually of about 100 ft. radius, is hung from the hoist tower direct by means of a suspended boom and counter-weight chute. In the older or "line chute" method the chutes are suspended from a cable run between towers or between towers and anchorages.

The plant cost and installation, and the upkeep charges, as well, are usually higher for chuting than for wheeling plants. When chutes are used the labor required to take care of any given mixer capacity is the same at long distances as it is at the mixer, the increased distance to be covered being taken care of by added chutes. The plant investment and

installation cost, however, will vary with the distance to be spanned, for since the slope of the chutes with reference to the horizontal cannot be reduced below a certain fixed angle it follows that for long reaches there must be added the cost of the extra length of chute plus a charge for the corresponding increase in the height of the tower.

There are, of course, many other factors affecting the choice between the two methods of placing in addition to the few that have already been mentioned. Principal among these may be mentioned the character of the building; the cost of freight and repairs, interest on investment and the kind of equipment which is available as well as the amount of experience which local labor has had in concrete construction. These items will be dealt with in more detail in the analysis of the two systems.

As already mentioned, the first point to be considered is the character and type of building. It may be assumed that any typical building job can be wheeled, with the number of mixing plants depending upon the contractor's individual preference as to the distance he cares to wheel from the tower. As a rule this is limited to about 200 ft. parallel to the long axis of the building and 100 to 150 ft. across the building, or over an equivalent area. Whether the labor cost thus obtained can be economically lowered by a heavier investment in plant is usually the crux of the problem.

Chutes do not lend themselves so readily to all types of building, and it is here first that study is necessary. A nearly square structure is obviously best adapted for the 100 ft. radius type. The building should preferably have a high yardage or a number of stories, although "H" or irregular shaped buildings which may be enclosed in an approximate square can usually be handled as advantageously. Long narrow structures one or two stories high with low yardage are not adapted for this method of placing, for example. With the same plan of building, but with greater yardage and more floors, one 100 ft. radius plant may be used to pour part of the building and by chuting to a floor hopper cut approximately 130 ft. off the wheel required to reach the rest of the building. Two independent 100 ft. radius plants may be used; or one mixing plant, a line chute to a re-hoist tower, and 100 ft. radius plants mounted on both towers.

In other cases, two adjoining buildings may be reached by the one 100 ft. radius plant, or one building may be chuted in entirety and the chutes used only to deliver concrete to a floor hopper on the second building. For groups of isolated buildings, line chutes will sometimes solve the problem of material delivery to what would otherwise be inaccessible mixing plants by the installation of a central mixing plant and the distribution of the mixed concrete instead of the raw materials.

These are some of the cases where chutes may often be used to good advantage, although not necessarily with the greatest ultimate economy. The first step, however, as above stated, is to find out whether the job is one to which chutes will lend themselves without forcing. If by a general inspection of the conditions such is found to be the case, it is

then proper to outline a plant layout for each method of placing and make an analysis of the advantages and disadvantages of each.

The next step in the decision as to which type of plant is economical and suitable for a certain piece of work is to determine as accurately as possible the cost of each so that the one giving the lowest ultimate cost of mixing and placing concrete may be selected.

This ultimate cost as outlined in previous reports of this committee may be separated for the purpose of analysis into the following items:

1. Rental of Plant Involved.
2. Installation—Labor and Material.
3. Maintenance of Plant—Labor and Material.
4. Operation Cost of Plant—Labor and Material.

These four items will be explained more in detail as follows:

Item 1, Rental of Plant, is arrived at in several different ways by different contractors. The simplest, though not the most economical to the job, is to purchase suitable plant at the beginning of the work and sell the same upon the completion of the job; the difference between the purchase and the sale price then represents the charge to be made as rental of plant. It is interesting to note that this method of handling plant account is practiced by several of our largest and more progressive general contractors and eliminates the trouble of the plant yard and the accumulation and maintenance of quantities of partly worn out and more or less out-of-date machinery. This method of handling plant has several disadvantages other than lack of economy—in time of industrial expansion when suitable machinery may not be immediately available at the beginning of the work, or a period of depression at the end of a job, it may be impossible to dispose of the plant without a great sacrifice. It is equally impossible, of course, for a job to benefit from a reversal of these conditions.

The usual way to handle this account is for a general contractor to maintain a suitable plant yard and charge each job a rental for the itims of plant furnished to the work. This charge can be either a fixed amount agreed upon for the work in hand or a monthly rental for the various items of machinery furnished. The amount of rental depends upon the value of the machinery and the rapidity of its depreciation and varies generally from 5% to 15% per month of its initial value. Motors, engines, hoists, etc., with proper maintenance, will not depreciate in value more than 5% a month. Mixers, boilers, etc., will depreciate 10% per month and concrete carts, chutes and like items of plant will depreciate up to 15% per month. Other smaller items, such as belting, shovels, wheelbarrows, etc., which are apt to be used up or destroyed during the life of an average job, are not generally considered as plant but as supplies and are bought by the job and any salvage value which they may have upon

the completion of the work is credited to the part of the job for which they were purchased.

Some contractors who make a principle of maintaining no plant yard themselves, have to depend upon dealers whose business it is to rent out plant, and where this practice is followed, the average cost to the job is about 10% per month of the value of all machinery furnished.

The transportation of the plant, including freight, trucking, loading and unloading, both to and from the job, is a proper part of the plant rental item.

Item 2, Cost of Installation, includes all charges for labor and material entering into the setting up of the machinery at the beginning of the work. This includes the construction of storage bins, cement sheds, hoist towers, floor hoppers, run panels and such miscellaneous items as really form a part of the completed plant for mixing and depositing of concrete. This cost of installation also includes any additions to this plant or changes in the arrangement of the same which may be necessary during the operation of the job and also includes the cost of taking down the plant upon the completion of the work. The salvage of any lumber or timber of other items which enter into the construction of the plant but do not form a permanent part of the machinery, are to be credited to this item. It is generally found, however, that the salvage from lumber in bins, sheds, hoppers, etc., is only enough to pay for the labor of wrecking the same, so this item seldom becomes a credit of much amount.

The cost of running water lines to mixer, bringing in electric power with setting of transformers, switches, etc., must also be included. If steam is obtained from nearby sources cost of necessary connections and piping must be added.

Fuel to operate a steam plant or electric power charges are obviously operating costs.

Item 3, Maintenance, includes the cost of all labor and material used in maintaining the plant in good working order such as repairs to bearings and other worn parts of machinery, painting and cleaning of same at the termination of work so that the machinery may leave the job in as good condition as it arrived except for the ordinary wear and tear. To this item is also charged the cost of replacing parts broken during the life of the job.

Proper maintenance of chuting plant requires that daily inspection be made of the entire equipment to tighten up loose connections, see that guy lines are tight and properly secured, etc.

Item 4, Operating Cost of the Plant, is principally a labor charge, the only material entering into the same being the cost of fuel, water, lubricating oils, waste, etc., and electric power in case electricity is used instead of steam. The labor in this item includes the actual operatives of the plant such as engineers, firemen, hoist runners, mechanics, etc., as well as the

force of laborers employed in charging the mixer with the materials of concrete, and the larger force of laborers employed in moving run panels or chutes, as the case may be, as well as actually placing the concrete in the forms, whether it be by carrying or chutes.

It is logical to expect that any increase in expenditures for Items 1, 2 and 3 will cause a sufficient decrease in Item 4 to make the summation of the four items a minimum, for the object of the plant used is to get the concrete in the forms for the least amount of money and all charges against this part of the work are included in the four items outlined.

As already mentioned in previous reports of this committee, serious shortage in the labor market or necessity for extreme speed in placing concrete, may influence the choice of plant which would not normally be selected. The actual value of these two conditions can generally be determined with sufficient accuracy so that a proper weight may be given to their influence in changing any layout of plant which would normally be decided upon.

In the comparative analysis of the two methods of placing concrete the majority of items will be found common to both the wheeling and the chuting systems, although the charges for these items will often vary for each.

Principal among the items common to both will be:

Towers and guy lines.
Mixers.
Hoist drums.
Hoisting buckets.
Electric motors or steam engines and boilers and electric wiring or steam piping.
Concrete carts.
Floor hoppers, gates, etc.
Run panels with horses, etc.

In the case of a wheeling job, large numbers of carry-alls will be used with their necessary run panels and supporting horses. There will probably be a single drum type of hoist used and the hoist tower and floor hoppers will be built of wood. A number of carry-alls and run panels sufficient to reach the most remote parts of the work must be provided for. The size of the wheeling gang must be determined for the whole job as that sufficient to take care of a little more than the average haul which will be half way from the tower to the most extreme part of the building. The charging and placing gang will remain about uniform throughout the job.

Where chuting plant is decided upon, it will either be of the counterweight boom type or the line chute type. For the construction of which the report of this committee is limited, it will almost certainly be of the counterweight boom type.

In this case the special equipment will be about as follows:

Steel towers with base and head frame.
Sliding frame with hopper.
Boom and counterweight truss.
Extension chutes.
Special hoist bucket.
Intermediate hoppers or additional sliding frame and hopper.

There will be much heavier guy lines needed and many more of them as every other 20 ft. panel point of tower needs support. The hoist cable will be of greater length due to the increased height to which it is necessary to elevate the concrete. A double drum hoist will be necessary so that the second drum may be available for the movement of the sliding frame, with delaying operations. The motor and drum will have to be of considerably greater capacity due to the greater hoist, if the interval between batches is to be maintained. The number of carry-alls and run panels will be greatly decreased and eliminated entirely if it is found feasible to chute to all remote points of the building. This is seldom found to be the case and the increasing objection on the part of engineers to the direct placing of concrete in the forms from chutes will probably tend to the use of floor hoppers and a short haul by carry-alls with the resulting use of a smaller number of carry-alls and floor panels, rather than their entire elimination.

The charging and placing gang will be about the same as where chutes are not used. The actual operators of the plant such as hoist runners, firemen, etc., will be about the same whether the concrete be transported by chutes or by carry-alls. The cost of power whether steam or electricity, is considerably greater for the chuting than for the wheeling plant due to the increased hoist necessary.

If due to special conditions, such as the necessary transportation of considerable quantities of concrete long distances, it is decided that line chutes are more suitable, the special equipment will consist of principally:

Main hoist tower, generally of steel and of greater height than for either of the other layouts.

Auxiliary towers or heavy anchorages.

Line chutes and heavy supporting cables.

Special auxiliary chutes with gates taking off from the line chutes.

Special hoist bucket.

Heavy guy lines and anchorages for towers.

Heavier hoist equipment.

The summary of the cost of each type of plant upon which the charts are based shapes up about as follows when all items are considered, it being understood that the specific items of equipment given below are only for an example.

I. PLANT

Wheeling.		Chuting.	
Equipment.	Depreciation, per cent.	Equipment.	Depreciation, per cent.
Mixer, 1 yard	20	Mixer, 1 yard	20
Motor, 75 h. p.	20	Motor, 75 h. p.	20
Single drum hoist	20	Double drum hoist	20
100 ft. wood tower:		180 ft. steel tower	20
ft. b. m. lumber @ $ /M	100	1 additional sliding frame with 54 ft. straight back hopper	20
Tower hoppers:			
ft. b. m. lumber @ $ /M	100	Full set of tower bolts	100
Run panels and horses:		800 ft. ¾ in. hoist cable	50
ft. b. m. lumber @ $ /M	100	20 turnbuckles	..
1 yard hoist bucket	20		
350 ft. ¾ in. hoist cable @	50		
1500 ft. ⅝ in. guy cable @	50		
12 turnbuckles	..	Wiring or piping	100
		Sliding frame with boom and counter-weight truss, plant complete	20
Wiring or piping	100		
Concrete carts @	50	Blocks and tackle for boom	50
		Blocks for moving sliding frame, 1080 ft. ¾ in. cable	50

Also include bins, bulkheads, conveyors, elevators, or other mechanical equipment, forming part of set up. Usually these items will apply equally to wheeling and chuting plants.

II.—INSTALLATION.

Wheeling | *Chuting*

Excavation for grading for mixer plus sheeting and backfulling.

Setting up and dismantling motor, mixer and hoist.

Wheeling:

Building and dismantling wood tower.

Making floor hoppers.

Making run panels and horses.

Chuting:

Erecting and dismantling steel tower, rigging, chutes, etc.

Erection and dismantling of bins, bulkheads, conveyors, etc.

Electrical, plumbing and steamfitting work to connect up plant.

III.—MAINTENANCE.

Wheeling

Replacement of broken run-panels, horses and slides.

Inspection.

Chuting

Inspection, generally requiring an Ironworker foreman to tighten loose bolts, inspect tackler, etc.

IV.—OPERATING (CONCRETING).

Wheeling		*Chuting*
	Fuel or power, oil or waste.	
	Labor mixing, hoisting and placing.	
	Men charging mixer.	
	Men handling cement.	
	Men on mixer.	
	Hoisting engineer.	
	Fireman (if any).	
	Man on tower hopper.	
Men shifting run panels.		Men handling chutes.
Men wheeling on floor.		Additional labor to raise sliding frame and shift guys and anchorages.
	Men spreading and tamping.	
	Foremen.	
	Men on mixer.	
	Hoisting engineer.	
	Fireman (if any).	
	Man on tower hopper.	
Men wheeling on floor.		Men on chutes.
Men shifting run panels.		
	Men spreading and tamping.	
	Foreman.	

2.—STUDY OF CHARTS.

It was pointed out in last year's report of the committee that the arrangements of plant most frequently used in building construction can be classified as modifications of seven generals types.

To avoid the labor of repeated estimates of the cost of these layouts for different yardages it was suggested that the cost of each of those arrangements be platted in the form of a chart from which the cost per yard for plant and installation could be readily obtained.

The charts published a year ago are no longer suitable for use owing to the changed business conditions, as stated at the beginning of this report. The new charts which are presented this year are figured as follows:

(1) For each layout two sets of estimates have been prepared, one for wheeling and one for chuting plant.

(2) While a 1 yd. mixer is rarely used for jobs of less than 4,000 yd., the curves for one yard plants have been carried down to 3,000 yd. Three-quarter yd. mixers are often used for jobs up to 4,000 yd. so that the ¾ and 1 yd. plant curves will overlap between 3,000 and 4,000 yd.

(3) For jobs of less than 4,000 yd. the equipment used for mixing, hoisting and placing is assumed as ¾ yd. mixer, 2 yd. hoist bucket, single drum hoist, 50 h. p. electric motor, 50 ft. wood tower, 8 concrete carts and 300 ft. of run panels.

For jobs of more than 4,000 yd. it is assumed that there would be used 1 yd. mixer, 1 yd. hoist bucket, single drum hoist, 75 h. p. electric motor, 125 ft. wood tower, 12 carry-alls for placing and 400 ft. of run panels. One 30 ft. length of extension chute has been included.

Chuting equipment for jobs of all sizes is assumed as 1 yd. of the so-called "200 ft. radius" type, with which a double drum hoist would be used for convenience in raising and lowering the sliding frame. A ¾ yd. mixing plant would probably require not over a 120 ft. tower; for a 1 yd. plant a 180 ft. tower is commonly used.

As was pointed out last year these assumptions are for an average of several conditions of area and height for a given yardage and will therefore be likely to give a cost which will vary slightly from the cost obtained by actually figuring out a specific job. For this reason the final decision on any *large* job should be made from a special estimate rather than from the charts; as a small difference per yard will become quite important in the case of large yardages.

(4) *Cost of plant to the job* has been figured on a depreciation basis. The schedule below is reprinted from last year:

Bucket Elevator	40%
Carry-alls	50%
Concrete Bucket	20%
Hoists	20%
Mixers	20%
Motors	20%
Side Tip Cars	20%
Steel Hoist Tower	20%
Stiff-leg Derricks	20%

These figures were considered suitable for jobs of over 8,000 yd. which would be likely to run 9 months to 1 year. For jobs of the yardages between 4,000 and 8,000 on which the plant would be in use a lesser period than 9 months these charges would of course be high. On the ¾ yd. plants (jobs of less than 4,000 yards) the depreciation has been taken as 60% of the annual figure in the table.

Wood-frame structures such as bins, bulkheads, wood hoist towers, etc., were considered a total loss and the plant charged with their full value, owing to the varying practice among contractors with regard to selling or storing the salvaged lumber, etc. Labor required to dismantle will in general offset any salvage value of the lumber as such.

(5) *Installation.* Under installation was charged labor required to set up and dismantle the plant, as well as labor making up run panels,

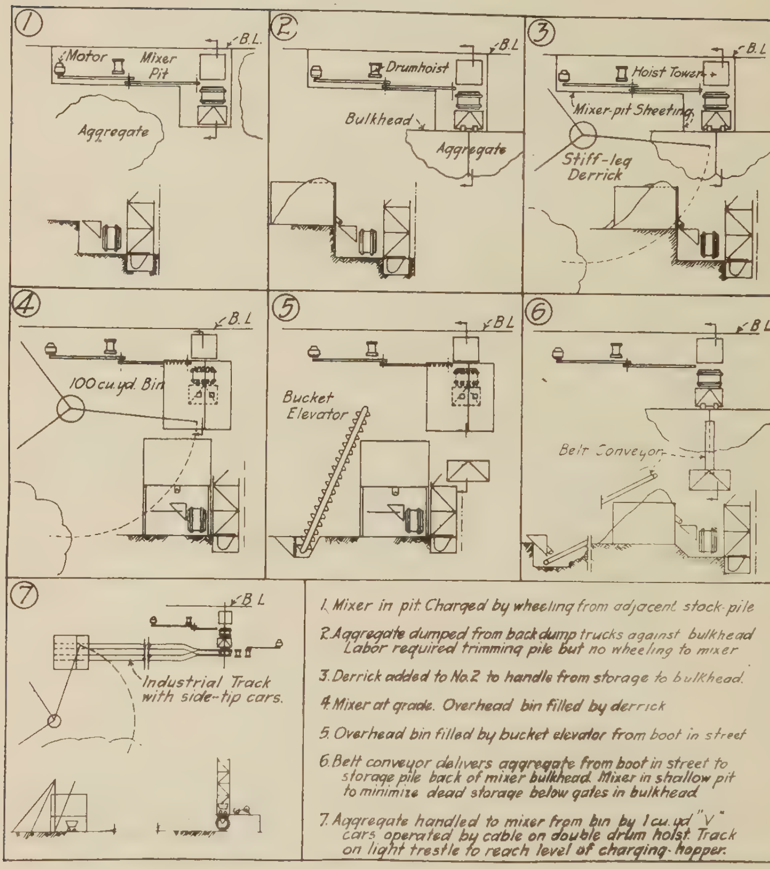

FIG. 1.—DETAILS OF SEVEN DIFFERENT PLANT LAYOUTS.

wood tower hoppers, conveyor supports, etc. Erecting steel hoist tower and hanging concrete chutes the first time is an installation charge. The subsequent moving of chutes about the floor, or the lifting of the sliding frame on the tower from floor to floor are charges against concreting.

An item frequently overlooked in estimating the erection cost of steel chuting towers is the bolts required. As it has been found that the number of usable bolts recovered is small it has become customary to cut them all off, thereby speeding the work and reducing labor cost on dismantling. A complete bill of bolts for a 180 ft. tower will run between \$100 and \$150 and must be given consideration.

(6) *Power, etc.*—Power of fuel, oil, waste, grease, etc., have been included in the form of a flat charge of .12c per yd. of concrete. As this

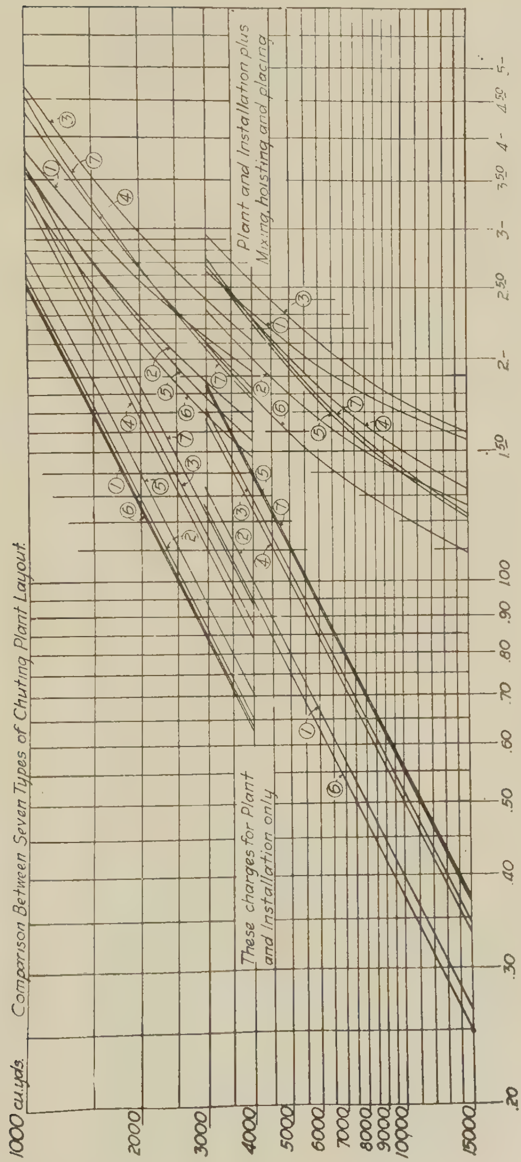

FIG. 2.—COMPARISON BETWEEN SEVEN TYPES OF WHEELING PLANT LAYOUT.

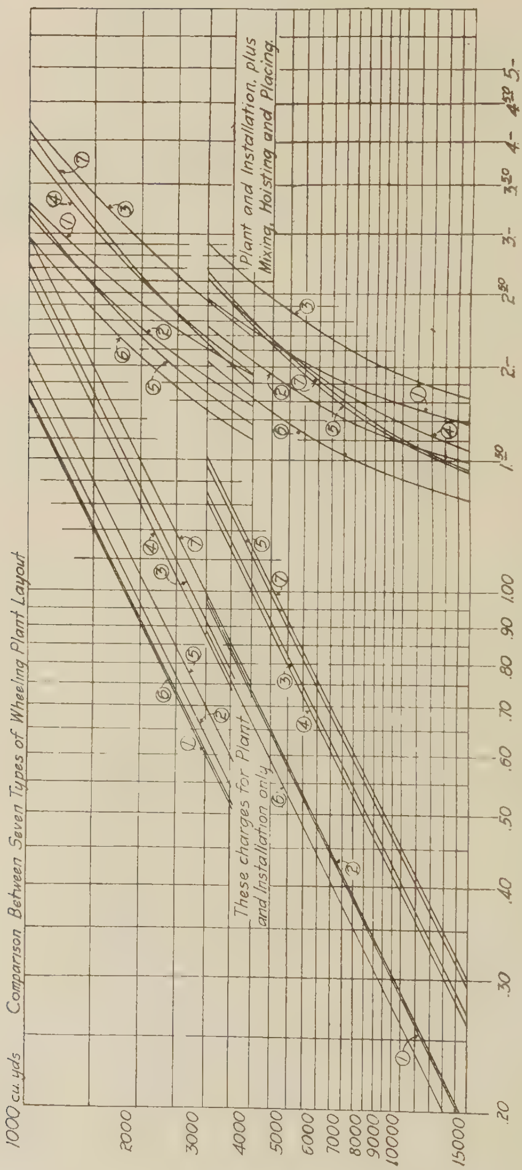

FIG. 3.—COMPARISON BETWEEN SEVEN TYPES OF CHUTING PLANT LAYOUT.

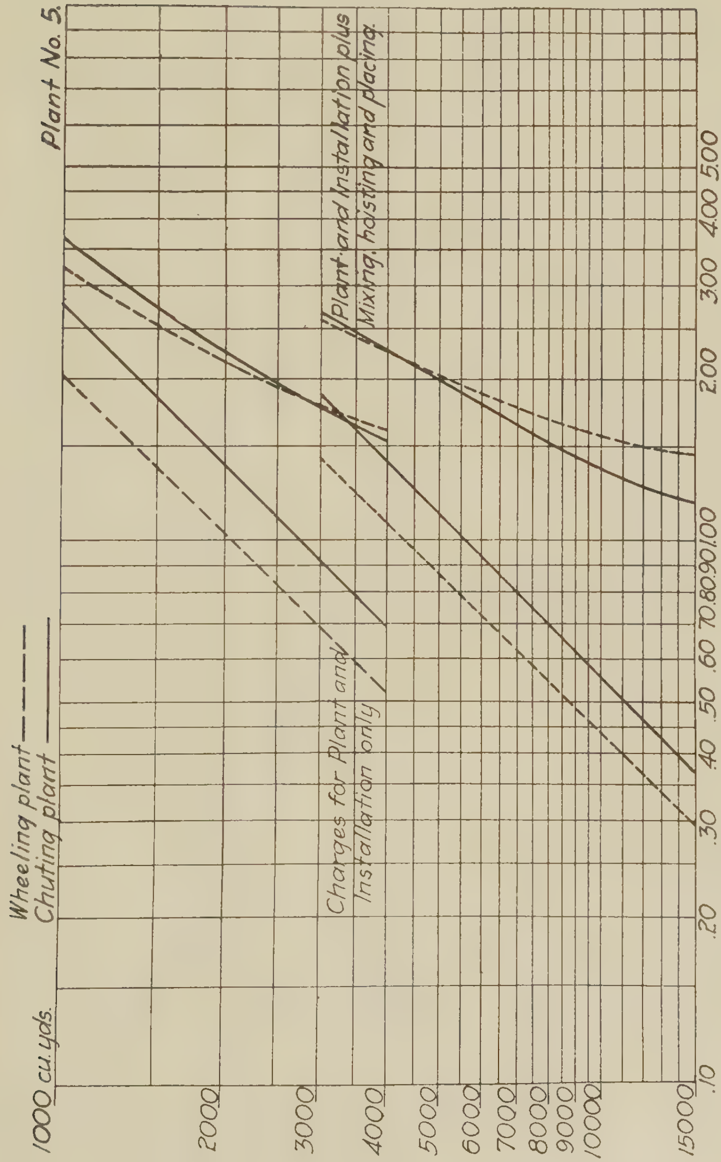

FIG. 4.—TYPICAL COMPARISON CURVE (FOR PLANT NO. 5).

is an operating cost, as distinct from the plant depreciation and installation costs it has been added to the labor unit for mixing, hoisting and placing.

(7) *Interest* on investment should be figured at 7% per annum on

TABULATION OF PLANT NO. 5

Yards.	¾ Yard.			1 Yard.		
	P. & I.	Labor.	Total.	P. & I.	Labor.	Total.
Wheeling Plant.						
1,000	2.092	1.15	3.242	4.443	....	....
1,500	1.395	....	2.545	.....	....	.....
2,000	1.046	....	2.196	.....	....	.....
2,500	0.837	....	1.987	.....	....	.....
3,000	0.697	....	1.847	1.481	1.15	2.631
3,500	0.597	....	1.747	1.269	....	2.419
4,000	0.522	....	1.672	1.111	....	2.261
5,000	.....	....	.....	0.887	....	2.037
6,000	.....	....	.....	0.74	....	1.89
7,000	.....	....	.....	0.634	....	1.784
8,000	.....	....	.....	0.555	....	1.705
9,000	.....	....	.....	0.494	....	1.644
10,000	.....	....	.....	0.443	....	1.593
11,000	.....	....	.....	0.404	....	1.554
12,000	.....	....	.....	0.370	....	1.520
13,000	.....	....	.....	0.342	....	1.492
14,000	.....	....	.....	0.317	....	1.467
15,000	.....	....	.....	0.296	....	1.446
Chuting.						
1,000	2.794	0.85	3.644	5.524	....	.....
1,500	1.864	....	2.714	.....	....	.....
2,000	1.397	....	2.247	.....	....	.....
2,500	1.119	....	1.969	.....	....	.....
3,000	0.932	....	1.782	1.841	0.85	2.691
3,500	0.798	....	1.648	1.58	....	2.430
4,000	0.698	....	1.548	1.382	....	2.232
5,000	.....	....	.....	1.104	....	1.954
6,000	.....	....	.....	0.922	....	1.772
7,000	.....	....	.....	0.789	....	1.639
8,000	.....	....	.....	0.691	....	1.541
9,000	.....	....	.....	0.614	....	1.461
10,000	.....	....	.....	0.552	....	1.402
11,000	.....	....	.....	0.502	....	1.352
12,000	.....	....	.....	0.461	....	1.311
13,000	.....	....	.....	0.425	....	1.275
14,000	.....	....	.....	0.395	....	1.245
15,000	.....	....	....	0.369	....	1.219

Submitted to whole committee and no criticism received therefore approved by same.

J. G. A.

the value of the mechanical equipment put on the job. Wood-frame structures are not carried by the contractor, but like the form-lumber are bought for and used up on the one job, and their cost becomes a part of the cost of the work. As the period for which interest is figured will vary with the period during which the plant is on the job, it may either

be put into the chart for an assumed average period, as was the depreciation, or it may be added in the summary. The latter method has been followed here.

These items comprise the charges against the plant for equipment and installation which are considered in the chart. To the total cost for plant, however, must be added the labor cost for mixing, hoisting and placing.

At the right of each chart is a set of curves in which this placing charge has been added to the plant cost. The labor unit is based on a rate of 4.50/8 hours, with labor efficiency at 100% as against approximately 90% for the corresponding time last year. The units used for the different plant layouts are given in Fig. 1.

(8) *Labor mixing, hoisting and placing* embraces broadly the gangs charging and running the mixer, the hoisting engineer, man on the tower hopper and the floor and the floor gang. The floor gang includes men wheeling, spreading and tamping as well as labor to lay and shift run panels or move chutes.

Time spent on receiving aggregate or cement is not included. It has been taken for granted that in receiving cement it would be piled alongside the mixer so that not more than two men would be required to open bags and empty into mixer hopper.

Plants 4 and 5 employ stiff-leg derricks. Their operation is not included in the cost of concrete as they would in all probability be used principally for unloading aggregate from cars or scows which would be a "receiving charge."

The data given are only for Plant No. 5.

JOHN G. AHLERS, *Chairman.*

Report of Committee P-1, on Standard Building Units.

We herewith submit our report with appended specifications for concrete brick and a separate specification for concrete building block and concrete building tile.

The work of Committee P-1 has been conducted to give absent members the benefit of reading the minutes of each meeting and they have been requested to send in their written opinions on the questions being discussed. The sitting members have tried to be governed by the expressed will of the majority. Many meetings have been held and an endeavor has been made to draft specifications which will be fair to the concrete products industry and to the users of the products.

The committee realizes the necessity of having specifications which will specify the requirements for concrete building units for varying services and for this reason have divided concrete block and concrete building tile into four classes.

Concrete brick have been considered as of but one class and that which will permit concrete brick to be specified for structures in the construction of which clay brick are preferred today. To increase the market for concrete brick the quality must be high.

J. W. Lowell and Stanton Walker were appointed a sub-committee to consider the subject of absorption and the recommendations of this sub-committee were considered in drafting the specifications for brick and for concrete block and concrete building tile.

We believe that the specifications presented are an improvement on existing Standard No. 10. It is our recommendation to the Institute that these specifications for concrete brick and for concrete block and concrete building tile be adopted and that Standard No. 10 be abolished. The specifications are printed on pp. 382 and 384.

The committee voted on the specifications as follows:

Votes on Specifications

Committee P-1

1923

	Block and Tile		Brick	
	Ayes	Noes	Ayes	Noes
Harris, W. R.	×		×	
Curtis, A. J. R.	×		×	
Carey, W. H.	×		×	
Crabbs, Austin	×		×	
Barnett, Edgar	×		—	—
Davis, H. A.	×		×	
Ferguson, J. A.	×		×	
Havlik, R. F.	—	×	×	
Kinzinger, F. J.	—	×		×
Lowell, J. W.	×		×	
Lindsley, C. E.	×		×	
Steward, C. A.	×		×	
Walker, Stanton	×		×	
Oehmann, J. W.	—		×	
Williamson, R. B. 0				
Barriball, George 0				
Benson, Newton D. 0				
Holsman, H. K. 0				
Schwan, G. H. 0				
Fellebaum, E. 0				
Brooke, B. E.	×		×	
Totals	12	2	13	1
Not voting	7		7	
Not voting on either	6		6	

Mr. Harris. W. R. HARRIS.—Although the committee has voted strongly in favor of the brick specification, S. L. Ekholm, a member of the Institute and a manufacturer of brick machines, takes exception to the report in that we ask for 1500 lb. strength against 1200 lb. for the highest grade of block. Bear in mind that the block is a hollow unit and the brick is a solid unit; then why should it not stand more? Bear in mind also that H. A. Davis, engineer for the Brooklyn Crozite Brick Co., a large manufacturer of brick, has expressed his opinion time and again regarding the specification and the committee has been guided by his knowledge. If Mr. Davis would have any objection to the strength, I think his objection should be borne in mind by the Institute, but he has made no objection.

I believe the strongest contention is against this 1500 lb. requirement, thinking that we are placing brick in a separate class. I believe we have complemented brick; I believe that if concrete brick are to compete with clay brick, they must be of similar quality. I believe the architects and engineers, members of this Institute, should express their opinion by voting either for or against the requirements. I believe the brick manufacturers should express their opinion. It is up to the architect and engineer to say what they want and the brick manufacturer to say what he can give, unless it is impossible to comply with the requirements. If requirements entail a hardship upon him, making the commercial structure of the product impracticable, that fact should be brought out.

Mr. Davis. H. A. DAVIS.—In connection with the specifications on concrete brick, as Chairman of the Sub-Committee of Committee C-3, on Concrete Brick, of A. S. T. M., I have been endeavoring to procure an acknowledgment of the reasonableness of a compressive strength requirement for concrete brick of 1500 lb. per sq. in. There has been a tendency in this committee on the part of certain members to consider that this is somewhat low. As a manufacturer of concrete brick it is essential that we secure a reasonable compressive strength requirement for concrete brick and comprehensive data and tests have been presented to both the committee of the American Concrete Institute and the A. S. T. M. to show that 1500 lb. per sq. in. is a reasonable requirement. Therefore Mr. Ekholm's request for a strength requirement lower than 1500 lb. per sq. in. is somewhat untimely and his suggestion that brick be similarly classified like block or tile in accordance with the wall in which used is somewhat impractical.

From experience in manufacturing and experimenting with various mixtures for concrete brick I believe that concrete brick can be economically manufactured to meet this requirement in competition with other products and it would be shortsightedness and inadvisable for a concrete brick manufacturer to sell brick having a strength very much below this stated requirement.

R. F. HAVLIK.—I am very much in favor of the brick specification, although the objections raised by Mr. Ekholm had not been called to my attention until after the thing was settled as far as the committee was concerned. He brought up one good point on brick and that is for non-load bearing brick, for which it seems to me we ought to make some provision similar to the block. Aside from that I think that brick that will not stand 1500 lb. per sq. in. is not fit to be used for load bearing purposes, because I just recently tried to use some. They were not very satisfactory and I sent some to Prof. Abrams to be tested at Lewis Institute. They tested 1290 lb. per sq. in., yet they were not the kind I would use regularly. The edges were rounded off and would crumble readily when you would handle them in the same way you handled clay brick. From the standpoint of brick for building purposes, where they carry a load, I believe 1500 lb. is the minimum we ought to ask for, but it does seem reasonable that for non-load bearing walls, we ought to make a reduction in the requirements for such brick. From the standpoint of block, I told the members of this committee, with whom I disagreed in the final vote, that if I could be shown how a builder could make provision to take care of the four or five classifications that we have in the specification that I would vote for it. Mr. Havlik.

A copy of that draft was sent to Committee S-5, and Committee S-5 made an attempt to provide for it in the Building Regulations; but the provision made only mentions the classifications, and in working it out I presume, from the way it read, that you could use the poorest block that would pass that specification which would mean a strength requirement of something like 500 lb. per sq. in. Personally I do not think we should increase the strength requirement for any kind of block or tile to 1200 lb per sq. in. as the proposed specifications do. I believe I have used as much block in important structures as any other man in the United States, and I have yet to find it necessary to make a stronger block than will pass a strength requirement of 1000 lb.

No one else thus far has found it necessary to make provision for it in a building code, and I am opposed to three or four classifications. If you adopt this, you will have no regulation that makes provision for it, and Committee S-5 has been unable to make provision for it. Where will we be? We will have a specification that we, as an Institute, cannot tell the other fellow how to make use of in a building. I think it would be a step backward rather than forward. That is one reason why I have suggested that the Building Code Committee and the Specifications Committee should be made one and the same, or else let the Building Code Committee first work out the requirements for building block to be used in buildings that will be O. K. in a building code, and then let the other committee tell us how to make the block to meet the building requirements.

J. W. LOWELL.—This committee tried for several years to write a specification embodying Mr. Havlik's ideas, but there must have been some- Mr. Lowell

Mr. Lowell. thing amiss because it could not be done. In the meantime that little spark of sound and enduring judgment which Mr. Havlik attempted to extinguish kept growing until it has at last formed itself into a definite recommendation, of which the committee justly feels proud.

Regardless of what is said against these specifications, they embody the following sound principles:

1. That just as there is need for more than one class of competitive product including monolithic concrete, so is there need for similar classes of concrete building products.
2. That competition in various building materials is keen; therefore, to require greater strength than that which is necessary for safety and endurable material would not be good engineering practise and might lead the concrete products industry to disaster.
3. That where the concrete is intended to carry loads or be exposed to disintegrating influences, such as the elements, a safe minimum strength of concrete should be adopted.
4. That within practical manufacturing limits the principle involved in designing the lighter building tiles is sound. This is, that where the actual volume of concrete in a building product is decreased and the remaining concrete made correspondingly stronger to offset the loss, the total strength of the product remaining the same as before, then the product is as good as it was originally from a structural standpoint and from a merchandising standpoint it may have other more desirable features.

The committee did not adopt arbitrary strengths for the various classifications of the concrete product. Months of study and discussion were devoted to this phase of the problem. We dug out all of the test reports of block, tile and brick that had been made during the past several years at the Structural Materials Research Laboratory, Lewis Institute, to determine whether we were specifying strengths above or below those being actually produced commercially by reputable manufacturers. Building requirements in cities where concrete building products are popular and well regulated were studied. The strength of competitive building products as specified by the American Society for Testing Materials and in public building codes, together with the structural performance of such products widely over the country was considered. Tests on the comparative efficiency of concrete and clay building products in the wall were made at the Structural Materials Research Laboratory for the benefit of the committee and tests made by others were also studied.

Mr. Hollister. S. C. HOLLISTER.—Classification for building tile or block will allow a solid block with an ultimate compressive strength of 250 lb. per sq. in. That seems to be pretty low. That, of course, is for a non-bearing wall. That is 250 lb. per sq. in apparently on the gross area, but there is no protection in article 5 to limit it from its being calculated also on the minimum cross section. I would like to know from the chairman of the committee whether that is intentional, to allow that unit stress on the solid block.

MR. HARRIS.—That is distinctly stated as non-load bearing units to be used in curtain walls which will only carry the weight of the block, the lowest course of block will carry the load of the superimposed layers. We have agreed that all concrete shall be equal to that which would give a strength of 1000 lb. per sq. in. of net area, irrespective of what we demand of gross area. Mr. Harris.

MR. HOLLISTER.—Is there any limit to the height of such a wall, in the mind of the Committee? Hr. Hollister.

MR. HARRIS.—There was none. We did not go into that for the reason that any building code committee could take that into account. We know that all of these classes of block are being made today and sold; for what purposes, we cannot say. I do know that in the city of Akron, there is one manufacturer who was blacklisted by the building department because he makes a block which fails at 270 lb. per sq. in. of gross area. All the other manufacturers are making block which comply with the requirement of 700 lb. per sq. in. We find that according to our specification that would be Class B. These classifications are not for anything except to give engineers and architects some means of grading block. They can say that according to A. C. I. standard number blank, that Class A, B, C or D block are required. It will be up to the manufacturer to supply those block. What we are trying to do is to furnish a specification which can be used by engineers and architects in defining what kind of concrete building units they want. We are interested in what our own building code committee does and we would like to work in conjunction with them. We do not believe that the action of the Institute is legislative action governing construction throughout North America; we believe that its action should guide engineers and architects and manufacturers. We believe that we should take a stand as to these classifications today, and it will then be up to the engineer and architect to state what he wants, to determine what strengths he wants to figure and see what loads he wants to place on A, B, C and D block. Mr. Harris.

TENTATIVE STANDARD SPECIFICATIONS FOR CONCRETE BRICK.*

Submitted by Committee P-1, on Standard Building Units.

1. The purpose of these specifications is to define the requirements for concrete brick to be used in construction.

2. The word "concrete" shall be understood to mean portland cement concrete.

Strength Requirements.

3. The average compressive strength of concrete brick 28 days after being manufactured or when shipped shall not be less than 1,500 lb. per sq. in. of gross cross-sectional area as laid in the wall, and the compressive strength of any individual brick shall not be less than 1,000 lb. per sq. in. of gross cross-sectional area as laid in the wall.

4. The gross cross-sectional area of a brick shall be considered as the product of the length times the width of the unit as laid in the wall.

Absorption Requirements.

5. Concrete brick shall not absorb more than 12 per cent of the dry weight of the brick when tested as hereinafter specified except when they are made of concrete weighing less than 140 lb. per cu. ft. For brick made of concrete weighing less than 140 lb. per cu. ft., the average absorption in per cent by weight shall not be more than 12 multiplied by 140 and divided by the unit weight in lb. per cu. ft. of the concrete under consideration.

Sampling.

6. Specimens for tests shall be representative of the commercial product of the plant.

7. Five specimens shall be required for each test.

8. The specimens used in the absorption test may be used for the strength test provided they have been dried at approximately seventy (70) degrees Fahrenheit for not less than three days.

METHODS OF TESTING.

Strength Test.

9. The specimens to be tested shall be carefully measured for overall dimensions of length, width and thickness, and shall be tested laid flat.

10. Bearing surfaces shall be made plane by capping with plaster of paris or a mixture of portland cement and plaster which shall be allowed to thoroughly harden before the test;

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*Accepted as Tentative Standard by the Convention, Cincinnati, Jan. 22, 1923.

11. Specimens shall be accurately centered in the testing machine;

12. The load shall be applied through a spherical bearing block placed on top of the specimen;

13. Metal plates of sufficient thickness to prevent appreciable bending shall be placed between the spherical bearing block and the specimen;

14. The specimen shall be loaded to failure;

15. The compressive strength in lb. per sq. in. of gross cross-sectional area is the total applied load in lb. divided by the gross cross-sectional area in sq. in.

Absorption Test:

16. The specimens shall be dried to constant weight at a temperature of from two hundred and twelve (212) to two hundred and fifty (250) degrees Fahrenheit and the weight recorded. After drying, the specimens shall be immersed in clean water at approximately seventy (70) degrees Fahrenheit for a period of twenty-four (24) hours. They shall then be removed, the surface water wiped off and the specimens re-weighed. The absorption is the weight of the water absorbed, divided by the weight of the dry specimen and multiplied by one hundred (100).

TENTATIVE STANDARD SPECIFICATIONS FOR CONCRETE BUILDING BLOCK AND CONCRETE BUILDING TILE.*

Submitted by Committee P-1, on Standard Building Units.

1. The purpose of these specifications is to define the requirements for concrete building block and concrete building tile to be used in construction.

2. The word "concrete" shall be understood to mean portland cement concrete.

Strength Requirements:

3. According to the strength in compression 28 days after being manufactured or when shipped, concrete block and concrete tile shall be classified as A—heavy load bearing, B—medium load bearing, C—light load bearing, and D—non-load bearing on the basis of the following requirements.

	Compressive strength, lb. per sq. in. of gross cross-sectional area as laid in the wall.	
Name of Classification	Aver. of 3 or more Units	Min. for Individual Unit
A—Heavy load bearing block or tile	1200	1000
B—Medium " " " " "	700	600
C—Light " " " " "	500	400
D—Non- " " " " "	250	200

4. The gross cross-sectional area of a one-piece concrete block or tile shall be considered as the product of the length times the width of the unit as laid in the wall. No allowance shall be made for air spaces in hollow units. The gross cross-sectional area of each unit of a two-piece block or tile shall be considered the product of the length of the unit times one-half the thickness of the wall for which the two-piece block or tile is intended.

5. The compressive strength of the concrete in units of all classifications except class "D" shall be at least 1000 lb. per sq. in., when calculated on the minimum cross-sectional area in bearing.

Absorption Requirements:

6. Concrete building block and tile to be exposed to soil or weather in the finished work (without stucco, plaster or other suitable protective covering) shall meet the requirements of the absorption test.

*Accepted as Tentative Standard by the Convention, Cincinnati, Jan. 22, 1923.

7. All concrete building block and tile not covered by paragraph 6 need not meet an absorption requirement.

8. Concrete block and tile shall not absorb more than 10 per cent of the dry weight of the unit when tested as hereinafter specified, except when it is made of concrete weighing less than 140 pounds per cubic foot. For block or tile made with concrete weighing less than 140 pounds per cubic foot, the absorption in per cent by weight shall not be more than 10 multiplied by 140 and divided by the unit weight in pounds per cubic foot of the concrete under consideration.

Sampling:

9. Specimens for tests shall be representative of the commercial product of the plant.

10. Not less than three and preferably five specimens shall be required for each test.

11. The specimens used in the absorption test may be used for the strength test provided they have been dried at approximately seventy (70) degrees Fahrenheit for not less than three days.

METHODS OF TESTING.

Strength Test:

12. The specimens to be tested shall be carefully measured for over-all dimensions of length, width and height.

13. Bearing surfaces shall be made plane by capping with plaster of paris or a mixture or portland cement and plaster which shall be allowed to thoroly harden before the test;

14. Specimens shall be accurately centered in the testing machine;

15. The load shall be applied through a spherical bearing block placed on top of the specimen;

16. When testing other than rectangular block or tile care must be taken to see that the load is applied through the center of gravity of the specimen;

17. Metal plates of sufficient thickness to prevent appreciable bending shall be placed between the spherical bearing block and the specimen;

18. The specimen shall be loaded to failure;

19. The compressive strength in pounds per square inch of gross cross-sectional area is the total applied load in pounds divided by the gross cross-sectional area in square inches.

Absorption Test:

20. The specimens shall be dried to constant weight at a temperature of from two hundred and twelve (212) to two hundred and fifty (250) degrees Fahrenheit and the weight recorded. After drying, the specimens shall be immersed in clean water at approximately seventy (70) degrees Fahrenheit for a period of twenty-four (24) hours. They shall then be removed, the surface water wiped off and the specimens re-washed. The absorption is the weight of the water absorbed, divided by the weight of the dry specimen and multiplied by one hundred (100).

Weight of Concrete:

21. The weight per cubic foot of the concrete in a block or tile is the weight of the unit in pounds divided by its volume in cubic feet. To obtain the volume of the unit, fill a vessel with enough water to immerse the specimen. The greatest accuracy will be obtained with the smallest vessel in which the specimen can be immersed with its length vertical. Mark the level of the water, then immerse the saturated specimen and weigh the vessel. Draw the water down to its original level and weigh the vessel again. The difference between the two weights divided by 62.5 equals the volume of the specimen in cubic feet.

TENTATIVE STANDARD SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE PAVEMENTS.*

ONE COURSE PORTLAND CEMENT CONCRETE PAVEMENT.

I. GENERAL.

(A) It is the intent of these specifications to cover the requirements for materials and construction of portland cement concrete pavement, wherein the concrete is of uniform proportions from top to bottom of the slab.

II. MATERIALS.

(*A*) *Cement* shall be a standard portland cement which at the time it is incorporated in the pavement mixture, shall conform to the Standard Specifications and Tests for Portland Cement (Serial Designation: C9-21) of the American Society for Testing Materials, and subsequent revisions thereof.

(*B*) *Aggregates.* Prior to placing any orders for aggregates the contractor shall advise the engineer of the proposed source or sources of supply of aggregates. The engineer may require the contractor to submit fifty (50) pound samples of all aggregates proposed for use. If the engineer finds such samples fulfill the requirements of these specifications for aggregates, similar material shall be considered as acceptable. Acceptance of samples shall not be construed as a guarantee of acceptance of all materials from the same source, and it shall be understood that any aggregates which do not meet with the requirements of these specifications will be rejected. Upon receiving notification of the proposed source or sources of aggregate supply, the engineer may elect to investigate and test the aggregate supply at the source; in which case he shall notify the contractor as to acceptability, or non-acceptability of the proposed aggregates. The engineer shall notify the contractor, after agreement upon a source or sources of aggregate supply, whether routine tests of aggregates during construction will be made at the source of supply or at the point of receipt. (See Bidding Sheet.)

(*a*) *Fine Aggregate* shall consist of natural sand, stone screenings, slag sand, tailings, chatts, or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains. When incorporated in the pavement mixture, fine aggregate shall be free from frost, frozen lumps, injurious amounts of dust, mica, soft or flaky particles, shale, alkali, organic matter, loam, or other deleterious substances. Ninety-five (95) per cent of the fine aggregate, when dry, shall pass a one-fourth (¼) inch screen; not more than twenty-five

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(25) per cent shall pass a fifty (50) mesh sieve, and not more than five (5) per cent by weight shall pass a one hundred (100) mesh sieve. In no case shall fine aggregate be accepted containing more than three (3) per cent, by dry weight, nor more than five (5) per cent by dry volume, nor more than seven (7) per cent by wet volume, of clay, loam, or silt. If any sample of fine aggregate shows more than seven (7) per cent of clay, loam or silt, in one hour's settlement after shaking in an excess of water, the material represented by the sample will be rejected. Fine aggregate shall be of such quality that mortar composed of portland cement and the fine aggregate when made into two (2) by four (4) inch cylinders, in the same proportions as will be used in the concrete mixture for the pavement, shall show compressive strength at seven (7) and twenty-eight (28) days equal to or greater than the compressive strength of cylinders composed of mortar of the same proportions of portland cement and standard Ottawa sand. For proportioning test cylinders, portland cement and fine aggregate and standard Ottawa sand shall be measured by weight, and the same portland cement shall be used with the Ottawa sand as with the fine aggregate to be tested.

(*b*) *Coarse Aggregate* shall consist of one of the following materials, or a combination thereof: crushed rock, pebbles (gravel), air cooled blast furnace slag, chatts or tailings. The particles of coarse aggregate shall be of clean, hard, tough, durable material, free from vegetable or other deleterious substances, and shall contain no soft, flat, or elongated pieces.

(Note: In many cases, it will be necessary for the engineer to specify the sizes, grading, and quality of coarse aggregate in accordance with local conditions. In every case, the engineer should provide specifications which will require the use of the best coarse aggregate which is economically available. As a guide to the engineer, Abrams' Tables of Proportions and Quantities for Concrete for Road Construction are printed herewith. The following specifications covering size and grading of coarse aggregate will be found applicable in most sections of the country, and are intended for use with the 1: 2: 3 or 1: 1½: 3, mixture.)

The size of the coarse aggregate shall be such as to pass a three (3) inch round opening. Coarse aggregate shall be uniformly graded within the limits shown in the following table, and any material which does not come within the limits specified shall be rejected.

Passing 3 inch round opening, 100%.

Passing 2 inch round opening, not less than 82% nor more than 95%.

Passing ½ inch round opening, not less than 10% nor more than 25%.

Passing ¼ inch sieve, not more than 5%.

Crushed Rock shall consist of particles of rock produced by quarrying and crushing ledge rock, field boulders, or pebbles, from which, after crushing, all dust and pieces below one-quarter (¼) inch size have been screened out. Crushed rock shall conform in quality to the specifications under *Coarse Aggregate.*

Pebbles (*Gravel*) shall consist of loose material containing only par-

ticles retained upon a one-quarter (¼) inch screen, resulting from the natural crushing and erosion of rocks. Pebbles must have wearing qualities at least equal to crushed stone. Pebbles shall conform in quality to the specifications under *Coarse Aggregate.*

Air Cooled Blast Furnace Slag shall consist of non-glassy particles, retained upon a one-quarter (¼) inch screen, reasonably uniform in density and quality and free from thin or elongated pieces and flux stone. It shall be air-cooled and exposed to the weather for a period. It shall contain not more than two (2) per cent of sulphur, and the dried slag when shaken to refusal shall have a weight of not less than sixty-five (65) pounds per cubic foot. In other respects, slag shall conform in general to the specifications under *Coarse Aggregate.*

Chatts, or Tailings are terms locally applied to by-products, or waste products, of certain mining and industrial operations. When used as coarse aggregate for concrete pavements, such materials shall substantially conform to the specifications under *Coarse Aggregate.*

(*C*) *Mixed Aggregate* shall consist of a combination of fine and coarse apgregates. That portion of mixed aggregate passing a one-quarter (¼) inch screen shall conform to the requirements for *fine aggregate;* and that portion of mixed aggregate retained on a one-quarter (¼) inch screen shall conform to the requirements for *coarse aggregate.*

(*D*) *Water* shall be clean, free from oil, acid, alkali, or vegetable matter.

(*E*) *Reinforcement* shall consist of steel fabric, or of steel bars, or a combination of both and shall have an effective weight exclusive of dowel bars at joints and of circumferential bars of at least ...... pounds per one hundred (100) square feet for steel having a minimum yield point of thirty-three thousand (33,000) pounds per square inch. For steel of intermediate grade having a minimum yield point of forty thousand (40,000) pounds per square inch the weight as above specified may be reduced twenty per cent (20%). For steel of hard grade having a minimum yield point of fifty thousand (50,000) pounds per square inch the weight as above specified may be reduced by thirty-three and one-third per cent (33⅓%).

(*a*) *Steel Fabric* shall be fabricated from cold drawn wire having a yield point of fifty thousand (50,000) pounds per square inch and shall otherwise comply with tentative standards of the American Society for Testing Materials, serial designation A 82-21 T.

The spacing of primary members shall be not more than ...... inches, and of secondary members not more than ....

(*b*) *Steel Bar Reinforcement.* This style of reinforcement shall consist of steel bars of the size, shape and spacing shown on the plans.

In no case shall the bars be spaced to exceed ...... inches for those laid perpendicular to the center line of the pavement and ...... inches for those laid parallel to the center line of the pavement. Steel bars shall comply with the standard requirements for Concrete Reinforcement Bars

of the American Society for Testing Materials, serial designation A15-14. All bar reinforcement, when placed in the pavement shall be free from excess rust scale or other substance which prevents the bonding of the concrete to the reinforcement. When in storage on the work, bars shall be protected from corrosion by placing them on a dry platform under a weatherproof cover.

(*F*) *Joint Filler* shall consist of prepared strips of fibre matrix and bitumen, containing not more than 25% of inert material, having thickness of .... inch, and width equal to .... inch greater than the thickness of the pavement at any point. The bitumen used in manufacture of the joint filler may be either tar or asphalt of a grade that will not become soft enough to flow in hot weather, nor brittle in cold weather. The prepared strips shall be cut to conform to the cross-section of the pavement and in lengths equal to the width of the pavement, except that strips equal in length to half the width of this pavement may be used when laced or clipped together at the center in a workmanlike and effective manner.

(*G*) *Shoulders.* (Any special materials for the construction of shoulders should be here described as desired by the engineer).

III. SUBGRADE.

(*A*) *Subgrade* will be considered as that portion of the highway upon which the pavement is to be placed.

(*B*) *Fine Grading* will include the finished excavation and embankment which may be necessary to bring the subgrade to the required elevation, alignment, and cross-section. All suitable materials removed from the excavation in fine grading shall be used as far as practicable in the formation of the embankment, as may be required. Such material not used in embankment may be deposited on the shoulders as directed by the engineer. When the amount of the embankment exceeds the amount of the material available from excavation, suitable material shall be obtained by the contractor from borrow pits located beyond the limits of the shoulders or embankment slopes. Such borrow pits shall be left in neat condition, such as will drain completely. Ditch sections and back slopes of cuts must conform to the plans, and be left with neat and uniform appearance.

(*C*) *Preparation and Maintenance of Subgrade.* The subgrade shall be constructed to have, as nearly as practicable, a uniform density throughout its entire width. Wherever the subgrade extends beyond the lateral limits of an old roadway, or wherever an old gravel, macadam, or other hard compacted crust comes within six inches of the elevation of the finished subgrade, such old roadway or crust shall be ploughed, loosened or scarified to a depth of at least six (6) inches and the loosened material redistributed across the full width of the subgrade, adding suitable material, when necessary, so that when compacted to the required

elevation, alignment, and cross-section, the subgrade will approach as nearly as possible, a condition of uniform density. Compression of the subgrade material shall be accomplished with a self-propelled roller weighing not less than three (3) tons. Hand-tamping portions of the subgrade may be directed by the engineer when necessary. There shall not be left on the subgrade or shoulders, berms or ridges of earth or other material that will interfere with the immediate discharge of water from the subgrade to the side ditches, and the subgrade shall be maintained free from ruts so that it will, at all times, drain properly.

All depressions developing under traffic on the subgrade, or in connection with rolling, shall be filled with suitable material. Rolling shall be continued until the subgrade is uniformly compacted, properly shaped, and true to grade and alignment. It is not intended that the rolling shall be continued beyond this point, as the purpose of rolling is not to produce a subgrade that cannot be further compacted, but to produce a *uniformly* compacted subgrade. All hauling shall be distributed over the width of the subgrade so far as practicable, so as to leave it in a uniformly compacted condition.

After being prepared in the above manner, the subgrade shall be so maintained until the concrete pavement has been placed thereon.

(*D*) *Checking and Acceptance of Subgrade.* Immediately prior to placing concrete pavement on the subgrade, it shall be checked by means of an approved scratch template, resting on the side forms, having the scratch points placed not less than eight (8) inches apart, and to the exact elevation and cross-section for the subgrade surface. The scratch template shall be drawn along the forms so that the plane of the points will be at a right angle to the grade line, and the long axis of the template at a right angle to the center line of pavement. All high places indicated by the scratch points shall be removed to true grade, and any low places back filled with suitable material and rolled or hand tamped until smooth and firm. The subgrade shall be checked and completed in accordance with these requirements for a distance of not less than one hundred (100) feet in advance of the concrete. If hauling over the subgrade after it has been finished and checked as above specified, results in ruts or other objectionable irregularities, the contractor shall re-roll or hand-tamp the subgrade and place it in smooth and satisfactory condition before the pavement is deposited upon it. If the condition of the subgrade is such that it cannot be placed in satisfactory condition to receive the pavement by the above methods, placing pavement may be stopped by the engineer unless the contractor can provide and haul over suitable trackways or use other satisfactory means for the protection and maintenance of the subgrade.

(*E*) *Special Treatment.* (Special treatment may be specified for certain subgrades such as sand, gumbo, adobe, and other materials, which can not be satisfactorily prepared for pavement by the methods specified in the foregoing paragraphs.)

IV. FORMS.

(*A*) *Materials.* Wooden forms shall be dressed to three (3) inch thickness, and equal in depth to the thickness of the pavement at the sides. Forms shall rest upon stakes driven into the ground within one (1) foot of each end of each separate piece, and at intervals not greater than five (5) feet elsewhere. Forms shall be held in place by stakes driven into the ground along the outside edge at intervals of not more than six (6) feet, two (2) stakes being placed one at each side of the joint. The forms shall be firmly nailed to the side stakes, and firmly braced at any point where necessary to resist the pressure of the concrete or the impact of the tamper. Forms shall be capped along the inside upper edge with two (2) inch angle irons.

Metal forms shall be of shaped steel sections not less than ten (10) feet in length, for tangents and for curves having radii of one hundred fifty (150) feet and over. For curves of less radii, sections five (5) feet long may be used. Forms must have a depth equal to the side thickness of the pavement. Forms shall be made of steel plate of at least number ten (10) gauge, and a form six (6) inches in depth shall weigh at least seven and one-half (7½) pounds per linear foot not including the fastenings. All forms shall be of approved section, having a flat surface on top not less than one and three-quarters (1¾) inches wide. At least three bracing pins or stakes shall be used to each ten (10) feet of form, and the bracing and support must be ample to resist the pressure of the concret and the impact of the tamper without springing.

(*B*) *Setting.* Forms shall set to exact grade and alignment at least two hundred (200) feet in advance of the point of depositing concrete. Before setting the sections must be thoroughly cleaned. After setting they shall be thoroughly oiled before concrete is placed against them. Forms in place will be subject to check and correction of line or grade at any time.

V. PAVEMENT SECTION.

(*A*) *Width, Thickness and Crown* of concrete pavement shall be as shown on the plans for the improvement.

VI. JOINTS.

(*A*) *General.* The joints to be formed shall be transverse or longitudinal. They shall be tested during and after finishing with a ten (10) foot straight edge and any irregularities in the surface shall be immediately corrected. Expansion joints shall be formed between the pavement under construction and all other rigid types of pavement or structures to which it may be adjacent. All joints shall be edged to a radius of one-eighth (⅛) of an inch. Joints shall be made as follows:

(*B*) *Transverse Expansion Joints.* Transverse expansion joints shall be (....) inch wide, spaced (....) feet apart. A bulkhead cut to the exact cross-section of the pavement, shall be securely staked in place at

right angles to the center line and surface of the pavement. The premolded joint filler shall be placed against the bulkhead and held in position by pins on which there is an outstanding lug. Concrete shall be deposited on both sides of the bulkhead before it is removed. After the concrete has been struck off the bulkhead shall be removed by lifting it slowly from one end and replacing it with concrete as it is lifted, so that the joint-filler will be left in the correct position.

When expansion joints are made at the end of the day's work they shall be formed by finishing the concrete to the bulkhead, placed as before specified. When work is resumed the joint-filler shall be placed against the hardened concrete and held in position by pins until fresh concrete is placed against it.

In pavements with integral curb the joint shall be continuous in a straight line through pavement and curb.

Joints shall be opened on the edges of their entire depth, upon removal of the forms.

Before the pavement is opened to traffic the joint filler shall be trimmed off to a uniform height of one-quarter (¼) inch above the surface of the pavement.

(*C*) *Longitudinal Joints.* Longitudinal expansion joints shall be formed by placing the filler against the form, bulkhead, curb, or adjacent structure and placing the concrete against it. The filler shall extend the full depth of the pavement, and be flush with the pavement surface.

(*D*) *Transverse Construction Joints.* Transverse construction joints shall be formed whenever it is necessary to stop concreting for thirty (30) minutes or longer, except at expansion joints, by staking in place a bulkhead, as specified for transverse expansion joints, and finishing the concrete to the bulkhead. An edging tool shall be used along the bulkhead to make the construction joint a regular and well defined line. In this bulkhead there shall be holes spaced three (3) feet, center to center, three (3) inches below the surface of the finished pavement, through which three-quarter (¾) inch steel plain round or square rods four (4) feet long shall be inserted with two (2) feet projecting. One-half of the length to the bar shall be encased in heavy paper or coated with paint or oil in such manner as to prevent a bond between the steel and the concrete.

When work is resumed the plank shall be removed, care being taken not to disturb the rods or the concrete. The fresh concrete shall be placed directly against the face of the concrete previously laid and carefully worked around the rods.

If concreting must be stopped within ten (10) feet of a previously made transverse joint the concrete shall be removed to this joint.

(*E*) *Longitudinal Construction Joints.* Longitudinal construction joints shall be formed where required and must be straight and vertical. When so indicated on the plans, steel dowels shall be used as provided in (D).

VII. WATER SUPPLY.

(*A*) *Equipment.* Where necessary for the supply of water for all operations described in these specifications, duplicate pumps, connected to an adequate pipe line along the improvement, shall be provided by the Contractor. The pipe line must be fitted with drains at the low points, and air relief valves at the high points, and with convenient outlets for all paving operations. Where the concrete mixer operates on the subgrade, the pipe line shall have a minimum diameter of two (2) inches. For supplying a mixer using more than four (4) sacks of cement per batch, sixty (60) per cent. of the pipe line shall have a minimum diameter of three (3) inches, and the remaining forty (40) per cent. shall have a minimum diameter of two (2) inches. The large diameter pipe shall lead from the pump.

(*B*) *Priority to Water Supply.* The concrete pavement in place, for ten days after laying, and the subgrade preparation, shall have prior rights to the water supply. If it should develop there is not sufficient water for all purposes, the concrete mixer shall be shut down until the water needs of the curing and subgrading operations have been cared for.

VIII. PROPORTIONING AND MIXING CONCRETE.

(*A*) *Measuring Materials.* The method of measuring the materials for the concrete, including water, shall be such as to insure the required proportions of each of the materials as directed by these specifications. One (1) sack of portland cement (94 pounds net) shall be considered one (1) cubic foot.

(*B*) *Proportions.* The concrete shall be proportioned one (1) sack of portland cement, not more than............cubic feet of fine aggregate, and not more than..........cubic feet of coarse aggregate. The amounts of portland cement, fine and coarse aggregates for one (1) cubic yard of concrete shall be as set forth in Abrams Tables, printed herein, for the sizes and gradings of aggregates used. A cubic yard of concrete in place, measured between neat lines, must contain............barrels of portland cement. The Engineer shall compare the calculated amount of cement required by these specifications and tables with the amounts actually used in each section of concrete.............feet long, or between successive transverse joints. If the amount of cement actually used in the pavement varies from the specified amount by more than three (3) per cent. for any section, the engineer may require the proportions of the concrete to be adjusted so as to use the specified amount of cement. If it is found that the amount of cement used in any section is ninety-two and one-half (92½) per cent. or less, of the specified quantity, the contractor shall be required to remove such section or sections, and replace them with concrete made in accordance with these specifications. Such removal and replacement shall be done at the expense of the contractor.

(*a*) *Proportioning Concrete with Mixed Aggregates.* When the con-

tractor desires to use mixed aggregate, he shall notify the engineer at least fourteen (14) days in advance of the time paving operations are to be commenced. The engineer shall make necessary arrangements for screen analysis of the mixed aggregate, in order that the proportions for concrete may be adjusted as often as may be required by changes in the grading of the mixed aggregate. Mixed aggregates may be proportioned either by weight or by volume. When proportioned by weight, the proportions shall be in accordance with the following table. When proportioned by volume, the ratios will depend upon the weights per cubic foot of the aggregates and will be established by the engineer.

TABLE OF PROPORTIONS FOR MIXED AGGREGATE.

Per cent of material passing one-quarter (¼) inch screen to total weight of mixed aggregate.	Pounds of portland cement to pounds of mixed aggregate.	Approximate barrels of portland cement per cubic yard of concrete.
33	1 : 5.18	1.6
34 to 40	1 : 4.84	1.67
41 to 45	1 : 4.59	1.74
46 to 50	1 : 4.34	1.80
51 to 55	1 : 4.10	1.87
56 to 60	1 : 3.84	1.95
61 to 65	1 : 3.60	2.04
66 to 70	1 : 3.35	2.15
71 to 75	1 : 3.10	2.26
76 to 80	1 : 2.86	2.39
81 to 85	1 : 2.61	2.53
86 to 90	1 : 2.36	2.71
91 to 95	1 : 2.12	2.89
96 to 100	1 : 1.87	3.13

(*C*) *Mixing.* The concrete shall be mixed in a batch mixer, with the "boom and bucket" type of delivery. The capacity of the drum shall be such that only whole bags of cement are used in each batch. Mixing shall continue for at least one (1) minute after all materials, including water, are placed in the drum, and before any part of the batch is discharged. The drum shall be revolved not less than fourteen (14) nor more than eighteen (18) revolutions per minute. The drum shall be completely emptied before receiving materials for the succeeding batch. The volume of the mixed material in each batch shall not exceed the mixer manufacturers rated capacity of the drum.

The mixer shall be provided with a water measuring tank into which mixing water shall be discharged, having a visible gauge so that the amount of water for each batch may be separately and accurately measured. The mixer shall be provided with an approved batch timing device which will automatically lock the batch discharging device during the full mixing time and release it at the end of the mixing period. The timer device shall have a bell which will automatically ring at the start and end of the mixing period. This device shall be subject to inspection and adjustment by the engineer at any time.

(*D*) *Retempering.* Mortar or concrete which has partially set shall not be retempered by being mixed with additional materials or water.

(*E*) *Central Mixing Plants.* The use of central mixing plants and the transportation of mixed concrete is permitted under these specifications, provided there is no segregation of the mixed concrete when it is delivered at the point where it is to be deposited in the pavement. The period between mixing and placing in the pavement shall not exceed forty (40) minutes, and this period may be reduced at the direction of the engineer. The concrete must be of workable consistency when placed on the subgrade.

(*F*) *Consistency.* The concrete mixture shall contain no more water than is necessary to produce a workable mass which can be brought to a satisfactory finish in the pavement. The amount of water used shall not exceed six and one-quarter (6¼) gallons per sack of cement, when the aggregates are dry.

IX. PLACING CONCRETE AND REINFORCEMENT.

(*A*) *Rechecking Subgrade.* Immediately before placing concrete, or any type of reinforcement, thes ubgrade shall be rechecked by means of a scratch template as provided in section III (D) of these specifications, and any inequalities corrected as therein provided.

(*B*) *Condition of Subgrade.* Concrete shall be placed only on a moist subgrade, but there shall be no pools of standing water. If the subgrade is dry, it shall be sprinkled with as much water as it will absorb readily. The engineer may direct that the subgrade may be sprinkled or thoroughly wet down from twelve (12) to thirty-six (36) hours in advance of placing concrete, where such procedure may be deemed necessary.

(*C*) *Placing Reinforcement.* Steel fabric reinforcement, of the size and weight shown on the plans, shall be placed two (2) inches below and parallel to the finished surface of the pavement unless otherwise indicated. Fabric shall extend to within two (2) inches of sides and ends of slabs. All laps of fabric sections shall be not less than three-fourths of the spacing of members in the direction lapped. Steel bar reinforcement shall be placed two (2) inches below the finished surface of the pavement unless otherwise indicated on the plans. Transverse bars shall extend to within two (2) inches of the margins of the pavement. Bar reinforcement shall be placed and securely supported in correct position before any concrete is laid. All intersections of longitudinal and transverse bars shall be securely wired or clipped together to resist displacement during concreting operations.

(*D*) *Placing Concrete.* The mixed concrete shall be deposited rapidly on the subgrade to the required depth and for the entire width of the pavement section, in successive batches and in a continuous operation without the use of intermediate forms or bulkheads between joints. While being placed, the concrete shall be vigorously sliced and spaded with suit-

able tools to prevent formation of voids or honeycomb pockets. The concrete shall be especially well spaded and tamped against the forms. When the concrete is placed in two horizontal layers to permit use of steel reinforcement, the first layer shall be roughly struck off with a template or screed, riding on the side forms, at the correct elevation to permit placing the reinforcement in specified position. The concrete above the reinforcement shall be placed within fifteen (15) minutes after the first layer has been placed. Any dust, dirt or foreign matter which collects on the first layer shall be carefully removed before the upper layer is placed.

In case of a breakdown of the mixer, involving stopping operations for more than forty (40) minutes, a transverse joint shall be formed at the point directed by the engineer, to close the section. Any concrete in excess of that needed to complete a section, when work is stopped for more than forty (40) minutes shall not be used in the pavement.

(*E*) *Finishing.* Experienced and skillful workmen must be employed at all times for preparing the surface of the pavement. The concrete shall be brought to the specified contour by means of a heavy screed or template, fitted with handles, weighing not less than fifteen (15) pounds per linear foot. This screed or template may be of steel, or of wood shod with steel. It shall be shaped to the cross-section of the pavement, and have sufficient strength to retain its shape under all working conditions. The template or screed shall rest on the side forms and shall be drawn ahead with a sawing motion. At transverse joints, the template shall be drawn not closer than three (3) feet toward the joint, and shall then be lifted and set down at the joint and drawn backwards away therefrom. Surplus concrete shall then be taken up with shovels and thrown ahead of the joint.

(*a*) *Belting.* The concrete shall be finished by using a belt of wood, canvas, or rubber, not less than six (6) nor more than twelve (12) inches wide, and at least two (2) feet longer than the width of the pavement. The belt shall be applied with a combined crosswise and longitudinal motion. For the first application vigorous strokes at least twelve inches long shall be used, and the longitudinal movement along the pavement shall be very slight. The second application of the belt shall be immediately after the water sheen disappears, and the stroke of the belt shall be not more than four inches and the longitudinal movement shall be greater than for the first belting.

(*b*) *Machine Finishing.* When a finishing machine is used it shall be so designed and operated as to strike off and consolidate the concrete, eliminating ridges and producing a true and even surface. The operation of the machine shall be so controlled as to keep the coarse aggregate near the finished surface of the pavement. Repeated operation of the machine over a given area is to be avoided.

A hand tamping template and belt must be kept for use in case the tamping machine breaks down.

(*c*) *Longitudinal Floating.* Immediately after the screeding specified under IX (E) has been completed, the surface should be inspected for high or low spots and any needed corrections made by adding or removing concrete. Rough spots should be gone over with a long handled float and worked to proper contour and grade. The entire surface shall then be floated longitudinally, with a float board not less than sixteen feet long and eight inches wide. This float board shall have convenient plow-handles at each end. It shall be operated by two men, one at each end, each man standing on a bridge spanning the pavement. The lower surface of the float board shall be placed upon the surface of the concrete with the long dimension parallel to the center line of the pavement. The float shall then be drawn back and forth in slow strokes about two feet long, and advancing slowly from one side of the pavement to the other. The purpose of this operation is to produce a uniform even surface on the concrete, free from transverse waves. The two bridges on which the workmen stand should be placed about eighteen (18) feet apart when the length of the float is sixteen (16) feet. When the entire width of the pavement has been floated in this manner from one position of the bridges, they shall be moved ahead about twelve feet so that the next section to be floated shall overlap the one previously so floated from three (3) to four (4) feet. After this floating has been completed, and all transverse waves eliminated, the surface shall be finished by the belting process specified in IX (E a).

(*d*) *Finishing at Joints and Tooling.* The contractor shall provide a suitable split float or split roller, having a slot to fit over expansion joints. This device shall be so arranged as to float the surface for a width of at least three (3) feet on each side of the joint simultaneously. This device shall be used in such a manner as to produce a true surface across the joint. Edges of the pavement, at joints and side shall be tooled for a width of two (2) inches, the corners rounded to a radius of one-quarter (¼) inch.

(*e*) *Trueness of Surface.* The finished surface of the pavement must conform to the grade, alignment and contour shown on the plans. Just prior to the final finishing operation, the surface shall be tested with a light straight edge, ten (10) feet in length, laid parallel to the center line of the pavement. Any deviation of one-quarter (¼) inch or more shall be immediately corrected.

The contractor shall be held responsible for the trueness of surface of the pavement, and shall be required to make good any deviation from the alignment, grade, and contour shown on the plans, in excess of the tolerance stipulated in this section.

X. CURING AND PROTECTION.

(*A*) *Burlap Cover.* The contractor shall provide a sufficient amount of burlap or canvas for every mixer on the job, to cover all of the pavement laid in any one day's maximum run. Burlap or canvas cover shall be made up in sheets twelve (12) feet wide, and four (4) feet longer than

the width of the pavement. Burlap or canvas cover shall be placed on the concrete immediately after the final belting, and shall then be sprayed with water in such a manner that the surface of the pavement will not be damaged. Burlap or canvas cover shall be kept continuously moist by spraying until the concrete has taken final set.

(*B*) *Wet Earth Cover.* As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than two (2) inches of earth, or six (6) inches of hay or straw. This cover shall be kept continuously wet by spraying for ten (10) days after the concrete is laid.

(*C*) *Sprinkling or Ponding.* The sprinkling system of curing may be used if approved by the engineer. The sprinkling equipment shall be placed carefully, and without injuring the concrete surface. The sprinkling system shall be so arranged, and supplied with sufficient water at ample pressure, to keep every portion of the pavement surface continuously wet (both night and day) for ten (10) days after laying the concrete. Dikes shall be constructed along both edges of the pavement, with cross-dikes where necessary, and the water flowing off the surface of the pavement shall be collected and led to the ditches or culverts as directed by the engineer. The contractor shall be held responsible for any damage to the roadway, shoulders, or adjacent property, by reason of escaping water.

The ponding system of curing may be used at the option of the contractor. Dikes shall be built along both edges of the pavement, with cross-dikes at sufficiently frequent intervals, and the pavement flooded with sufficient water within the dikes to keep all portions of the pavement surface continuously covered with water for ten (10) days after the concrete is laid.

(*D*) *Cleaning.* After fourteen (14) days, the earth or other cover may be removed. After thirty (30) days, the contractor may use a mormon or a fresno scraper to remove the cover, except that scrapers shall not be used within one (1) foot of expansion joints. Cover within one (1) foot of expansion joints must be removed by hand. Road machines, or blade graders of the two (2) or four (4) wheel type shall not be used for removing the cover.

After the cover has been removed, or ponds emptied and dikes removed, the entire surface of the pavement shall be swept clean and free from dirt and debris. Horse or motor drawn sweepers shall not be operated on the pavement till thirty (30) days have elapsed after the concrete is placed.

(*E*) *Cold Weather Protection.* Concrete shall not be mixed nor deposited when the temperature is below freezing, except under such conditions as the engineer may direct in writing. If, at any time during the progress of the work, the temperature is, or in the opinion of the engineer, will, within twenty-four (24) hours, drop to thirty-eight (38) degrees Fahrenheit, the water and aggregates shall be heated, and precau-

tions taken to protect the concrete from freezing until it is at least ten (10) days old. In no case shall concrete be deposited upon a frozen subgrade, nor shall frozen materials be used in the concrete.

XI. PROHIBITION OF TRAFFIC.

(*A*) *Barricades.* The contractor shall provide and maintain substantial barricades across the pavement, with suitable warning signs by day and by night, to prevent traffic of any kind upon the pavement before it is thirty (30) days old or before the cover has been removed. The contractor shall provide and maintain watchmen at each mixer, whenever the paving crew is not at work, who shall prevent destruction or removal of barricades, and keep traffic off the pavement.

No section of pavement shall be opened to traffic until written instructions have been given by the engineer.

(*B*) *Crossings.* At public highway and private crossings, the contractor shall provide suitable structures to carry the traffic across the pavement without injury to the concrete. All such structures shall be subject to the approval of the engineer, and he may direct their improvement, or repair, as conditions may require.

XII. CONDITION BEFORE ACCEPTANCE.

(*A*) *General.* Before the road will be considered completed in accordance with these specifications, and acceptable to the engineer, the pavement, shoulders, ditches, back slopes, and structures, shall be placed in a neat and orderly condition, conforming to the plans and specifications in all respects. Equipment, surplus materials, and construction debris of every description shall be removed from the right of way.

DISCUSSION.

E. E. HUGHES *(by letter)*.—Our attention has been called to "Specifications for Portland Cement Concrete Pavements" as tentatively adopted at the meeting of the American Concrete Institute in Cincinnati on Jan. 22, 1923. **Mr. Hughes.**

We are particularly interested in Section E, Sub-section 2, covering Steel Reinforcement Bars, which refers only to American Society for Testing Materials Specification, Serial Designation A-15-14.

The purpose of this communication is respectfully to suggest to the committee that they broaden this section to include rail steel bars manufactured in accordance with American Society for Testing Materials Specification, Serial Designation A-16-14.

To determine the merit of this suggestion requires the consideration of only two influencing factors:

(1) Will bars meeting A. S. T. M. Specification A-16-14 be satisfactory for reinforcement of concrete highways?

(2) What benefit will be gained by broadening the specification to include these bars?

The answer to the first is readily apparent by an examination of the specifications themselves. Specification A-15-14 covers three grades of billet bars—structural, intermediate, and hard grade. Specification A-16-14 covers rail steel bars and it is exactly the same as the other specification covering hard grade billet bars. If one is admitted, there is no reason for excluding the other. This similarity is further borne out by the fact that Thos. H. MacDonald, Chief Engineer, U. S. Bureau of Public Roads, has placed rail steel bars on the same basis as hard grade billet bars for all federal aid work.

It is true that highway engineers have in the past exhibited a preference for soft steel for reinforcing roads. Apparently this preference has been due to their belief that harder steel would not so successfully withstand the shocks and vibrations in road and bridge construction. However, there is no supporting data for this belief, while on the contrary there are available any number of tests that have shown hard grade bars to withstand the most abnormal shocks when imbedded in concrete.

There are hundreds of concrete bridges and viaducts, and miles of concrete pavements reinforced with Rail Steel Bars. There is not one single failure amongst these and to the present day they are giving just as good service as similar structures in which other reinforcement was used.

Therefore, in the fact of facts that confirm the suitability of rail steel bars for reinforcing highway structures, and the total absence of any evidence to the contrary, we are unwilling to believe that engineers will

restrict the specifications to one kind of material and thus stifle competition. This brings us to the consideration of the second influencing factor.

Under the specification as it now stands, the builders of roads are restricted to the use of one kind of reinforcing bar, regardless of the advantages, either in price or service, which might be obtained in particular localities for materials under other specifications.

This is a general specification prepared for the guidance of engineers and builders throughout the country. It is comparable to a building code of a city and should not be any more specific than is necessary to guarantee safe construction. It should be broad in its requirements so as to encourage individuality in design and construction and to allow of economic selection of materials, the choice of which will vary in different localities.

Bars under Specification A-15-14 are manufactured in quantities only at the large steel producing districts—Pittsburgh, Chicago, and Birmingham, and are usually sold on a Pittsburgh basis.

Bars under Specification A-16-14 are manufactured not only in these steel producing districts but at several other central points, and are sold f. o. b. the mill producing them. This competition has a stabilizing influence, which affects favorably the price of bars bought under any specification.

It was recently pointed out by Mr. Hoover in discussing national highways that tests on rail steel bars had shown them to be satisfactory for reinforcing concrete roads, and that this was of considerable importance from an economic standpoint. This statement sums up and confirms what has just been said, and coming from Mr. Hoover emphasizes the importance of encouraging competition and thus promoting economy in the construction of highways.

These advantages are of such importance as to warrant the earnest consideration of the committee during the coming year and to justify their broadening the scope of these specifications before their final adoption.

Report of Committee P-6, on Concrete Product Plant Operation.

The preliminary report of this Committee consisted of a series of pertinent questions grouped under three general classifications, as follows:

1. Cost-keeping in the Products Plant,
2. Continuity of Plant Operation,
3. Consideration of ways to cut costs and produce products of uniform and acceptable quality.

Your chairman believing that these questions were of considerable interest to a great many products manufacturers, sent out letters urging several of our most successful and progressive products manufacturers to come to this convention prepared to discuss these questions and formulate a report on as many of them as time would permit for presentation at the convention and for the benefit of those who were unfortunate in not attending. I am glad to say that there was a large attendance of block manufacturers at the convention and most of these men were active in the discussions of the committee at its meetings prior to its scheduled meeting.

I. *Cost-keeping in the Products Plant.*—That this was the most important topic was unanimously agreed; therefore, it was given first consideration. It was generally thought that much of the ill feeling among competitive concrete products manufacturers over price problems and sales ethics arises from the lack of general knowledge in the industry of proper cost-keeping methods. Competing manufacturers at present have no common standard system of cost-keeping and as a rule the smaller manufacturers do not feel able to pay for proper advice on cost accounting.

A standard system of cost-keeping if adopted by a large number of manufacturers would tend toward greater development of manufacturing operation, more stable prices and a more favorable opinion of the industry by capital.

The suggested outline of cost items, sometimes termed the "card of accounts," in their logical order was considered thoroughly and adopted in the form shown on p. 405:

After adopting this classification, it is necessary to arrange certain cost record sheets on which to actually collect the information from day to day. Just how this can be best accomplished is a problem.

Agreement could not be reached on (1) whether a perpetual inventory and cost record is of enough importance to justify the expense of keeping it; (2) the extent to which costs should be subdivided and detailed; (3) whether local conditions such as the variety of products made and size of plant would affect the design of the recording system.

SYSTEM OF COST-KEEPING FOR CONCRETE PRODUCTS MANUFACTURERS.

CARD OF ACCOUNTS.

Investment, Land, Buildings, Equipment.

1. *Raw Materials (including cost of transportation and unloading charges):*

    Cement.
    Sand.
    Pebbles.
    (Itemized materials which enter into the product manufactured.)

2. *Direct Labor:*

    All productive labor used from the point where the materials are taken from the bins to and including manufacturing of the product and putting it into the storage yard. This labor to include foreman and assistants when they are engaged in productive labor.

3. *Indirect Charges:*

    Salaries of superintendent, foreman and assistants when engaged in non-productive labor.
    Rentals
    Repairs to buildings, Repairs to equipment — not estimated but exact expense incurred

    Depreciation on building—Wooden buildings 3 per cent, buildings with masonry wall 2 per cent. This figure may be exceeded when buildings are on leased ground.

    Depreciation on equipment—Machinery from 10 per cent to not over 15 per cent. Other equipment less than 10 per cent.

    Fuel, Light, Power — these may be combined if from one source.

    Miscellaneous supplies—including all supplies necessary to running the factory not included elsewhere.
    Breakage and losses of product.
    Taxes—Itemized to include all taxes on property.
    Insurances—Itemized to include fire, theft and liability.

Total Manufacturing Cost.

(Sum of all items above.)

4. *General Administration and Selling Expense:*

Salaries:

Officers, general manager and other employes, not including salesmen.

Selling organization.

Selling expense—including all miscellaneous expenses incidental to selling, such as entertainment, donations, promotion, not included elsewhere.

Advertising—although an indirect selling expense, it is so prominent it is separated from others.

Printing, supplies and postage—including all supplies and printing incidental to running the office, but does not include those used in advertising.

Telephone and telegraph—including all expenses in both factory and office.

Traveling—railroad fares, automobile expense, carfare, etc.

Collection expense
Legal expense } may be combined.

General taxes—All taxes not included elsewhere.

Interest paid—itemize all interest actually paid for whatever reason on money borrowed for the conduct of the business and not represented by stock or other participation in the dividends or earnings of the company.

Discounts:

On purchases.

On sales.

Total Commercial Cost.

(Sum of all items above.)

5. *Loading Expense:*

Total commercial cost (for comparison with those who include loading expense in their total commercial cost).

(Sum of all items above.)

6. *Delivery Expense:*

Total commercial cost (for comparison with those who include delivery expense in their total commercial cost).

(Sum of all items above.)

Most everyone agreed, however, that the method of recording costs should be such that an inventory and summary of costs could be obtained without undue effort and that such should be made at not too great intervals. Also, that the system should be subdivided sufficiently to give an intelligent record of the major items of expense and less important items

could be ascertained by special cost investigation whenever such information is desired.

Your Committee presents for consideration the following type of perpetual inventory form as having considerable merit. (Fig. 1.)

A second type of form offering a great deal of merit is that shown in Fig. 2, used by the Calumet Concrete Construction Co., Chicago.

From the entries on the sheet it is evident that this form of daily report for the factory is so arranged that the manufacturer can keep his costs in considerable detail. It is suggested that the space alloted to materials used might be increased if other materials enter into the process.

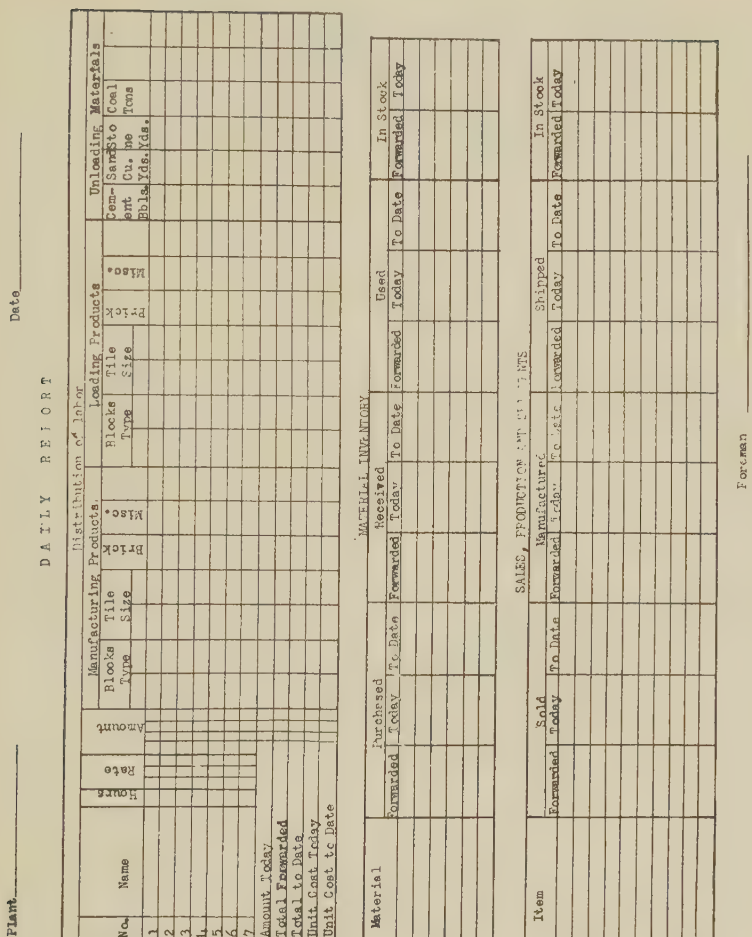
Another method of recording cost information of considerable merit is that used with success in the plant of The Cement Products Co. at Davenport, Iowa, owned by Austin Crabbs. Mr. Crabbs uses three sheets, shown in Figs. 3-5 inclusive. Each workman fills in the small slip, Fig. 3. The foreman makes out a daily report, Fig. 4, showing the quantity of product manufactured and the materials. A space under "Remarks" is provided for miscellaneous records, such as breakdowns, affecting results of the day. These various data are assembled on the "Cost Order," Fig. 5, in such a manner that costs for each month are comparable. With this system, costs of any particular item of production on which more information is desired may be obtained at any time by issuing a special cost order for the purpose of studying that particular operation alone.

There probably are manufacturers who think that a cost-keeping system is not justified in a small produts plant, or they are too busy during the daytime and too tired at night to look after it. We are firmly convinced, however, that an intelligent record of the cost of doing business is an absolute necessity and that the manufacturer cannot afford to do business without it.

II. *Continuity of Plant Operation.*—Products manufacturers should strive to keep their plants operating throughout the entire year to secure the greatest economy in production. When designing and building plants, it is desirable to bear this in mind so that the plant will not be too large for the available market and will operate economically under varying weather conditions. Since a plant that operates throughout the year must stock considerable raw material and finished product at certain times during the year, the facilities for such storage must be provided.

As a concrete illustration of the advantage of operating a block plant through the year as against closing down during the winter, the Committee has worked out Figs. 6-7, the first representing a small, and the second a medium-sized plant.

These comparisons show only the bare figures, or the tangible quantities, but there are other factors worth perhaps even greater consideration. Men prefer permanent positions and steady work rather than temporary positions and intermittent work. Therefore, the manufacturer who provides his men steady employment can get the best men and mold them into an efficient and loyal organization which will effect economies that cannot be duplicated under the temporary employment system.



DAILY REPORT

Plant ______ Date ______

Distribution of labor

No.	Name	Hours	Rate	Amount	Manufacturing Products: Blocks Type	Tile Size	Brick	Misc.	Loading Products: Blocks Type	Tile Size	Brick	Misc.	Unloading Materials: Cement Bbls.	Sand Cu. Yds.	Stone Cu. Yds.	Coal Tons
1																
2																
3																
4																
5																
6																
7																
Amount Today																
Total Forwarded																
Total to Date																
Unit Cost Today																
Unit Cost to Date																

MATERIAL INVENTORY

Material	Purchased: Forwarded	Today	To Date	Received: Forwarded	Today	To Date	Used: Forwarded	Today	To Date	In Stock: Forwarded	Today

SALES, PRODUCTION AND SHIPMENTS

Item	Sold: Forwarded	Today	To Date	Manufactured: Forwarded	Today	To Date	Shipped: Forwarded	Today	To Date	In Stock: Forwarded	Today

Foreman ______

FIG. 1.—DAILY REPORT FORM SUGGESTED BY THE COMMITTEE.

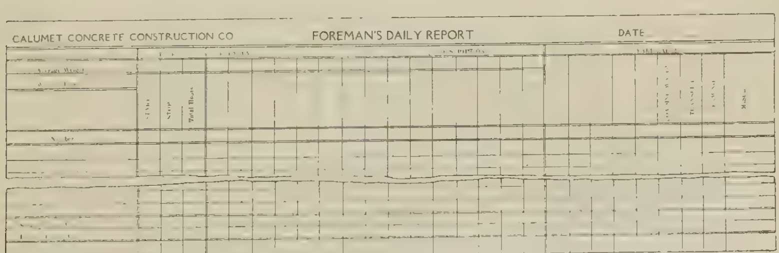


FIG. 2.—FOREMAN'S DAILY REPORT USED BY THE CALUMET CONCRETE CONSTRUCTION CO., CHICAGO. ACTUAL SIZE, 11 X 17 IN.

THE CEMENT PRODUCTS CO.

DAVENPORT, IOWA, ...

KIND OF WORK	HOURS
TOTAL	

Signed: ....

FIG. 3.—DAILY TIME SLIP KEPT BY EACH WORKMAN. ACTUAL SIZE $3\frac{1}{2} \times 5\frac{1}{4}$ IN.

DAILY REPORT

THE CEMENT PRODUCTS CO.

DATE ..

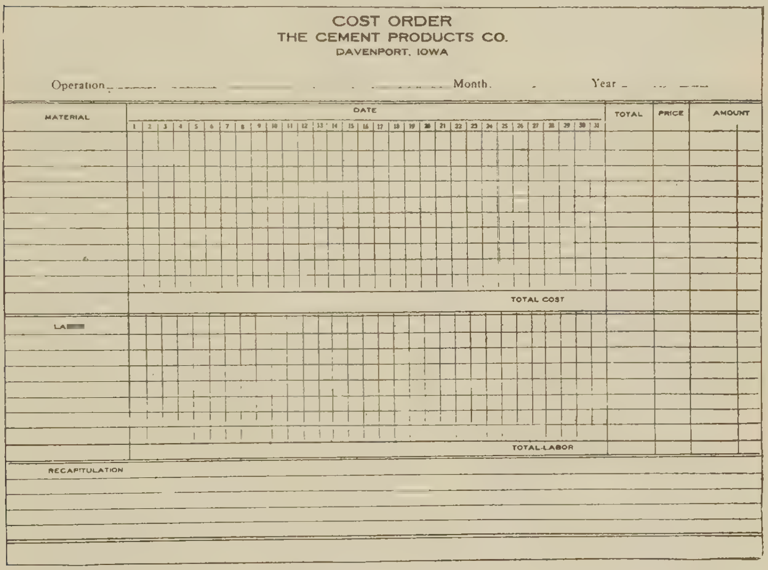
QUANTITY	DESCRIPTION	CEMENT	SAND	WHITE CEMENT	WHITE SAND		

Remarks:

FIG. 4.—DAILY REPORT SHEET FOR MATERIALS. ACTUAL SIZE $5\frac{1}{2} \times 8\frac{1}{2}$ IN.

III. *Consideration of Ways to Cut Costs and Produce Products of Uniform and Acceptable Quality.*—Although the concrete products plant presents ideal conditions for the practical application of the basic principles of making good concrete at the least cost, we regret that this has been largely overlooked by the manufaturer. This indicates, however, that there are tremendous opportunities for development in machinery and factory practices effecting large economies.

A practical demonstration was arranged by the Committee to show the workability which produces the greatest strength of concrete with the


COST ORDER
THE CEMENT PRODUCTS CO.
DAVENPORT, IOWA

Operation .... Month .... Year ....

MATERIAL	DATE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	TOTAL	PRICE	AMOUNT
	TOTAL COST			
LABOR				
	TOTAL LABOR			

RECAPITULATION

FIG. 5.—COST ORDER FORM FOR SUMMARY. ACTUAL SIZE 8½ X 11 IN.

least quantity of cement used with any given aggregate. The object of this demonstration was to (1) show that concrete of a consistency giving maximum strength can be used in the tamp type machine; (2) show manufacturers that to get uniformly good results it is necessary to accurately measure the quantity of water in successive batches.

The demonstration was arranged at the Ideal Concrete Machinery Co.'s plant at Cincinnati, where an Ideal building tile machine was loaned for the occasion. The Committee had previously secured an aggregate suitable for the purpose of making concrete to be molded into light products of section thickness from ½ in. to 1 in. and with cement proportions of from 1 : 4 to 1 : 7. The amount of water in the aggregate was determined by drying out a sample just prior to the demonstration and this

Fig. 6.—Cost Analysis of the Manufacture of Concrete Block, Showing Advantage of Twelve Months' Operation.
(1000–Block Plant)

	Equipment..... $5,500.00 Building........ 7,500.00 Land........... 2,000.00 Total......... $15,000.00	Equipment..... $5,500.00 Building........ 5,500.00 Land........... 2,000.00 Total......... $13,000.00
	Plant Operating 9 Hours per Day for 12 Months (281 Days), Making 281,000 Block.	Plant not Operating December, January, February, or March. Operating 9 Hours per Day for 200 Days, Making 200,000 Block.

	Total Cost	Cost per Block	Total Cost	Cost per Block
Raw Materials for 1000 Block:				
15.6 bbl. cement @ $2.40................	$37.44		$37.44	
14.4 cu. yd. aggregate @ $0.80...........	11.52		11.52	
Water................................	0.00		0.00	
	$48.96	$0.0490	$48.96	$0.0490
Direct Labor:				
Mixer man @ 45c per hour..............	$4.05		$4.05	
Operator @ 50c " "	4.50		4.50	
Off bearer @ 40c " "	3.60		3.60	
Yard man @ 40c " "	3.60		3.60	
2 laborers @ 40c " "	7.20		7.20	
	$22.95	0.0230	$22.95	0.0230
Indirect Charges:				
Salary, Mgr., $250.00 per month..........	$3,000.00		12 mo. $3,000.00	
Repairs to buildings....................	150.00		110.00	
Repairs to equipment....................	825.00		(12%) 660.00	
Depreciation on bldg....................	(3%) 225.00		225.00	
Depreciation on equipment...............	(15%) 825.00		(12%) 660.00	
Fuel....................................	800.00		400.00	
Light and power.........................	400.00		300.00	
Lubr. and misc. supplies................	150.00		100.00	
Taxes, $2.00 per $100.00................	300.00		300.00	
Liability insurance.....................	155.64		110.77	
Fire insurance..........................	125.00		125.00	
	$6,955.64	0.0248	$5,990.00	0.0300
Total manufacturing cost............		$0.0968		$0.1020
General Administration and Selling Expense:				
Salary, Office Force, $125.00 per month ...	$1,500.00		8 mo. $1,000.00	
Selling expense.........................	300.00		300.00	
Advertising.............................	1,000.00		1,000.00	
Printing and supplies...................	300.00		200.00	
Telephone...............................	60.00		60.00	
Traveling...............................	600.00		400.00	
*Interest paid..........................	000.00		000.00	
	$3,760.00	0.0134	$2,960.00	0.0148
Total commercial cost...............		$0.1102		$0.1168
Interest:				
On Accts. Receivable..................	6% on $7,500 $450.00		6% on $5,400 $324.00	
On Inventory..........................	310.00		000.00	
Investment............................	6% on $15,000 900.00		6% on $13,000 780.00	
	$1,660.00	0.0059	$1,104.00	0.0055
Total commercial cost for comparison with companies that include their items in their "Total Commercial Cost".........................		$0.1161		$0.1223
Cost of year's operation	281,000 blk. @ $0.1102	$30,966.20	200,000 blk. @ $0.1168	$23,360.00
Sales at 16c per block..................		44,960.00		32,000.00
Profit..................................		$13,993.80		$8,640.00

* Interest actually paid on money borrowed for the conduct of the business and not represented by stock or other participation in the company should appear opposite the item "Interest Paid" under the division "General Administration and Selling Expense" and, therefore, it affects the "Total Commercial Cost."

We have shown in detail, under the heading "Interest," figures which would be included if the entire business was conducted on borrowed capital.

Fig. 7.—Cost Analysis of the Manufacture of Concrete Block, Showing Advantage of Twelve Months' Operation.
(400–Block Plant)

One Power Tamp Machine

	Total Cost	Cost per Block	Total Cost	Cost per Block
	Equipment..... $3,300.00 Building........ 3,200.00 Land........... 1,500.00 Total......... $8,000.00		Equipment..... $3,000.00 Building........ 2,500.00 Land........... 1,500.00 Total......... $7 000.00	
	Plant Operating 9 Hours per Day for 12 Months (281 Days), Making 112,400 Block.		Plant not Operating December, January, February or March. Operating 9 Hours, per Day for 200 Days, Making 80,000 Block.	
Raw Material for 1000 Block:				
15.6 bbl. cement @ $2.40	$37.44		$37.44	
14.4 cu. yd. aggregate @ $0.80	11.52		11.52	
Water	0.00		0.00	
	$48.96	$0.0490	$48.96	$0.0490
Direct Labor:				
Mixer man @ 45c per hour	$4.05		$4.05	
Operator @ 50c " "	4.50		4.50	
Off bearer @ 40c " "	3.60		3.60	
	$12.15	0.0304	$12.15	0.0304
Indirect Charges,				
Salary, Supt., $200.00 per month	$2,400.00		12 mo. $2,400.00	
Repairs to building	75.00		60.00	
Repairs to equipment	495.00		360.00	
Depreciation on building (3%)	96.00		75.00	
Depreciation one quipment	(15%) 495.00		(12%) 360.00	
Fuel	300.00		100.00	
Light and power	200.00		130.00	
Lubr. and misc. supplies	100.00		75.00	
Taxes, $2.00 per $100.00	160.00		140.00	
Liability Insurance	97.60		66.90	
Fire Insurance	55.00		55.00	
	$4,473.60	0.0398	$3,821.90	0.0478
Total manufacturing cost		$0.1192		$0.1272
General Administration and Selling Expense:				
Salary, office force, $100.00 per month	$1,200.00		8 mo. $800.00	
Selling expense	100.00		100.00	
Advertising	300.00		300.00	
Printing and supplies	100.00		75.00	
Telephone	60.00		60.00	
Traveling	400.00		300.00	
*Interest paid	000.00		000.00	
	$2,160.00	0.0194	$1,635.00	0.0204
Total commercial cost		$0.1386		$0.1476
Interest:				
On Accts. Receivable	6% on $3,000 $180.00		6% on $2,200 $132.00	
On Inventory	120.00		000.00	
Investment	6% on $8,000 480.00		6% on $7,000 420.00	
	$780.00	0.0069	$552.00	0.0069
Total commercial cost for comparison with companies that include these items in their "Total Commercial Cost"		$0.1455		$0.1545
Cost of year's operation	112,400 blk. @ $0.1386	$15,578.64	80,000 blk. @ $0.1476	$11,808.00
Sales at 16c per block		17,984.00		12,800.00
Profit		$2,405.36		$992.00

* Interest actually paid on money borrowed for the conduct of the business and not represented by stock or other participation in the company should appear opposite the item "Interest Paid" under the division "General Administration and Selling Expense" and, therefore, it affects the "Total Commercial Cost."

We have shown in detail, under the heading "Interest," figures which would be included if the entire business was conducted on borrowed capital.

amount of water was figured as a part of the water for the mix. The concrete mixture used was 1 sack of cement to 4½ cu. ft. of aggregate, and the water cement ratio which is the volume of water divided by the volume of cement used in the batch was 0.807.

The concrete was mixed thoroughly in a Blystone batch mixer. The workability of this concrete was found to be just right for making tamped products. On a stripper machine water web marks would be formed on the stripped surface of the product. The workability of the concrete can be further described as follows: A ball of concrete made by working and compacting between the palms of the hands, just as in compacting a snowball, for half a minute will develop a very thin film of moisture on its surface.

The tile made were 5 in. high by 8 in. wide by 12 in. long. When tested at 41 days after being kept in damp sand three weeks, and dry for the remainder of the time, they averaged in weight 16.6 lb., in absorption 4.2% moisture, and in compressive strength 3270 lb. per sq. in. on the minimum area in bearing and 1340 lb. per sq. in. on the gross area. The total load carried by a tile was 119,830 lb. These figures are the average of four tile tested at the Structural Materials Research Laboratory, Lewis Institute, Chicago.

A sample of the aggregate used was sent to the physical laboratory of the Universal Portland Cement Co. at Buffington, Ind., where 2- x 4-in. cylinder tests were made using mixtures of 1 cement to 4½ aggregate and varying the water cement ratio both ways from that used in making the tile. The cylinders were stored 1 day in moist air and 27 days in water before they were broken with the following results:

FIG. 8.—TESTS SHOWING THE EFFECT ON THE STRENGTH OF 1:4½ CONCRETE BY CHANGING THE QUANTITY OF MIXING WATER.

Per cent of water above or below that giving greatest strength concrete	Water Cement Ratio	Strength of concrete per sq. in. in compression	Per cent of maximum strength
+20	.969	3317	72%
+15	.929	3812	83
+10	.888	3844	83.6
+ 5	.847	4428	96.5
* 0	.807	4585	100
— 5	.766	4535	98.5
—10	.726	4262	93
—15	.686	3848	83.5
—20	.646	3716	82

*This concrete was used in making tile.

The results of these cylinder tests prove that the water cement ratio we used in the tile gave the maximum strength concrete for a mixture of 1: 4½ using this particular grading of aggregate. When it is remembered that all of these mixtures are of dry consistency requiring tamping to compact them properly, it is of considerable interest to note that within these limits a considerable increase in strength might be realized and

more uniform results obtained by the manufacturer who applies this basic principle in his manufacturing process.

The tile which were made of the 1: 4½ mixture would conform with a generous margin to the American Concrete Institute tentative standard requirement for Class A tile, having a compressive strength of 1200 lb. per sq. in. on the gross area. Usually, however, light tile are made to conform to Class B, having a strength of 700 lb. per sq. in. on gross area. More cylinder tests were made similar to the first set except that the mix was 1: 7 and other consistencies were used as follows.

FIG. 9.—TESTS SHOWING THE EFFECT ON THE STRENGTH OF 1:7 CONCRETE BY CHANGING THE QUANTITY OF MIXING WATER.

Per cent of water above or below that giving greatest strength concrete	Water Cement Ratio	Strength of concrete per sq. in. in compression	Per cent of maximum strength
+41%	1.394	1792	—61½
+35	1.336	2080	71
+29½	1.278	2171	74
+23½	1.22	2484	85
+17½	1.162	2666	91
+11½	1.104	2711	92½
+ 6	1.046	2792	95
* 0	.988	2929	100
— 6	.930	2494	85

*This is the proper consistency for making tamped products.

First of all, it will be noticed that as the proportion of cement to aggregate becomes less the grading of the aggregate remaining the same, a larger water cement ratio is necessary to obtain the same workability. Here we find that 0.988 or approximately 1.0 is the water cement ratio giving the workability desired and incidentally, greatest strength concrete, whereas with the 1: 4½ it was 0.807. This second concrete mixed 1: 7 with a water cement ratio of 0.988 will result in tile passing the medium classification with a liberal margin. The variation in strength though from the proper water cement ratio to others that could be used again illustrates the advantage of applying this and other basic principles in practical plant production.

COMMITTEE P-6, ON CONCRETE PRODUCT PLANT OPERATION.

JOHN W. LOWELL, *Chairman.*

DISCUSSION.

Mr. Bosch. J. Bosch.—This subject of cost-keeping is to my mind one of the most important questions before the concrete products industry today. I am certain that if some of our competitors kept account of their costs as we do, there would be a far more friendly and co-operative spirit among us.

We have found that not only is it vital that we know what it costs us to do business, but it is important that we have our cost figures before us ready to present to our banker from time to time as we want our credit extended.

In that I have given a copy of our report form to the Committee, I wish to explain how it is used in the factory. The foreman places on the "Foreman's Daily Report" the description and number of each unit of product made and the time that each workman spends in making these products. Other tasks performed are listed and the time of the workmen employed on them is distributed accordingly. Then reports when turned in are completed by the bookkeeper.

Tasks that are directly performed in production are so charged, but those that are extraordinary, such as repairs, are entered in the ledgers under the proper heading according to our card of accounts. In this way, we make up our overhead charges which for convenience are based on the summary of annual performance. These figures are then reduced to a block unit for each type of block we make. The materials used are entered daily on the basis of pounds per block which units were arrived at by reducing annual figures.

Mr. Bliss. J. J. Bliss.—Could I ask Mr. Bosch how many block his company turned out last year?

Mr. Bosch. Mr. Bosch.—The Calumet Concrete Products Co. made 179,471 block in 1922.

Mr. Ashton. Ernest Ashton.—In making up daily cost on units of this kind, how are changes in inventory taken care of if fluctuations in market prices of raw materials occur?

Mr. Bosch. Mr. Bosch.—When making up our annual statement we use an average cost for raw materials. When raw material prices change it is a simple arithmetical problem to convert this to the block basis and correct for the percentage of difference to get the new cost for any particular day.

Mr. Bent. E. F. Bent.—For my own guidance, I should like to ask for information on the best way to distribute overhead or administrative charges to several plants—we have 8—some of which may operate only part time.

Mr. Ewing. Davis Ewing.—I am very much interested in the two tables worked out by Mr. Lowell's Committee which illustrate the possible economies in continuous operation. In fact, I was so interested when Mr. Lowell sent me his advance questionnaire that I had my bookkeeper work up a statement of our plant along similar lines to see how our experience would compare. Aside from the fact that our aggregates cost $2.07 per cu. yd.

instead of $0.80, our figures compare very favorably. I am fully convinced that any products manufacturer who will take the trouble of studying these tables in the committee's report will need no further argument to convince him that continuous operation is greatly to be desired. Mr. Ewing.

We try to operate throughout the year and in order to keep our factory running we never let up on our selling. The factory is equipped with 40 ft. high concrete stave silos filled by means of a bucket elevator run by a 5 hp. motor. Besides providing us with sufficient storage capacity to keep the plant going during the months while gravel cannot be obtained, we have also materially cut the cost of handling aggregates. Aggregates are drawn out of the bottom of these bins by gravity. In winter, a steam coil around the bin outlets keeps the aggregate moving freely and eliminates frozen material.

By watching market conditions and knowing the seasons of railroad and general commercial congestion in the building industry, we prevent running out of cement by stocking a sufficient surplus to tide us over these periods. A little surplus money invested in a plentiful stock of cement is the best insurance we know of to keep the plant operating. First of all, however, we must sell the product or at least create a market if one does not exist before the plant can be kept busy, and I should like to hear some discussion on that subject.

J. J. BLISS.—Although we have had plenty of the one-man-fly-by-night plant competition, we really have no competitors near our size in our market. The fact that we operate so that our block are there waiting to be delivered when the other fellow is closed up, and because we put out a uniformly good product and stand back of it, and because the buyers of block in our territory know all of this, is why we keep our plant supplied with business. Another reason is that we are confident that we can sell all the block we can make and are not afraid to make them ahead of the actual orders. Mr. Bliss.

W. R. HARRIS.—We have here a written discussion on this very topic, which, I am sure, will be of interest because the man who sent it in has accomplished something out of the ordinary in selling concrete building products. It is to be regretted that G. J. Lengst who wrote this discussion was unable to be here due to an injury. Usually, we think of a concrete block plant as a local proposition, but the plant Mr. Lengst has in Prairie du Chien, Wis., a town of less than 4,000, could supply the local community with all the building tile it needs with a very small portion of the plant's output. Also, there are no large cities close by. We will now read Mr. Lengst's discussion on "Marketing Concrete Building Tile and Brick." Mr. Harris.

G. J. LENGST—(read by W. R. Harris).—In 1919, I was in the building contracting business in Prairie du Chien, Wisconsin. At that time, it was practically impossible to obtain building materials, and in order to supply my own needs, I purchased a power concrete brick machine. For the first few months I used the entire output of the plant in my own construction activities. Mr. Lengst.

Mr. Lengst. The superior qualities of concrete brick over the clay brick marketed in this territory at once became evident to me and this fact, together with the demand on the part of other builders, induced me to start producing concrete building materials on a commercial scale. The demand soon became greater than the capacity of my plant. In order to expand, local capital was interested and the Prairie Concrete Products Company organized. A modern plant was built and equipped to manufacture structural tile, face and common brick, and concrete silo staves.

Concrete products must be sold. Unlike competitive materials which have been on the market for a long time and which have given general satisfaction, concrete products are comparatively new and, therefore, meet with considerable sales resistance on the part of individual builders, architects, engineers, contractors, public officials, and insurance underwriters.

Our market is chiefly in small towns within a radius of about two hundred miles in Wisconsin, and one hundred miles in Iowa. In the beginning, we sold direct to the builder and contractor. However, the impracticability of keeping in touch with each individual building project makes it evident that a larger field could be covered with less effort by establishing dealer agencies.

At the outset, we were able to obtain a capacity volume of business in this way. However, with the business depression which occurred the following year, it became necessary to establish more dealer agencies and to aggressively assist the dealer to sell our product.

We went about this by putting a live wire salesman in the field and by a direct mail advertising campaign. The salesman immediately established contact with the dealers and called on live prospects furnished by them. Many prospects were also obtained from various other sources, which he followed up and sold, turning the order over to the dealer for that territory.

Our salesman was supported by an educational campaign carried out by mailing circulars, post cards, etc., to a carefully selected mailing list. The material in the circulars consisted largely of reprints from various periodicals dealing with concrete, and general information on the use of tile and brick. The post cards were reproductions of buildings built of our material. This policy has been continued during the past three years with good results. Advertisements are also carried in the local papers, and programs of county fairs.

As a basis for all of our sales efforts it is, of course, necessary for us to furnish a high-grade product of uniform quality, and prompt service in the way of immediate shipments. It may be worth mentioning here that some of our hardest competition has been with the small manufacturers of concrete block who make an inferior product, and who in most cases, through lack of knowledge, sell it at less than cost.

There has been a considerable amount of prejudice to overcome in selling concrete products, but by an aggressive sales policy, square dealing, and by manufacturing a product of high quality, this prejudice has been largely overcome. As a result of our efforts, we have been able to do an

increasing volume of business each year, in spite of the general business depression which has occurred since our start. Mr. Lengst.

The problem of selling concrete products in the average community may be briefly stated as follows:

1. Make a product of good and uniform quality.
2. Secure a real salesman who is familiar with building construction.
3. Establish contact with dealers in buildinb materials and maintain their good-will by helping them get business.
4. Encourage the dealer to call upon you for assistance, and when he does call upon you, give him whole-hearted and prompt service.
5. Educate the contractors and builders in the use of your product.

J. W. LOWELL.—We have spent most of our allotted time discussing concrete building products from the viewpoint of the manufacturer, but we are fortunate in having with us representatives of two cities in which concrete building products are used very extensively. First, I am going to ask Mr. Schulz, representing the office of the Building Commissioner of Indianapolis, to discuss some of the problems in which he is interested. Mr. Lowell.

H. H. SCHULZ.—There are in the city of Indianapolis fifty-two concrete block plants using approximately 70,000 bbl. of cement and producing over four million concrete block annually, practically all of which are used locally. Our code, which was written some time ago when there were only a comparatively few block used, needs considerable revision to take proper care of our present conditions. The old ordinance requires that block have a compressive strength of at least 800 lb. on each square inch of gross area as laid in the wall. Last summer, we conducted a sort of round-up inspection of products and learned the startling fact that of 52 plants only three were making block to pass the requirement of 800 lb. The product of 25 plants ran as low as 600 lb. and the remainder were between 600 and 250 lb. In the fall, another similar inspection showed a somewhat better condition, but not satisfactory by any means. Further inspection of the plants and consultation with the manufacturers indicated that the reason for production of inferior products was not intentional, but rather carelessness, lack of knowledge of how to make concrete to comply with the requirements of our ordinance, and lack of proper equipment for turning out a uniform quality of product. Mr. Schulz.

With these conditions before us, we are called upon to write a new ordinance covering concrete building block that will be fair to the public and the manufacturer and one which can be enforced continuously with the least expense to the city.

With regard to quality of product, we have your tentative standard specifications as a guide. Most assuredly we must require the product of each plant to be marked for identification and perhaps the date on which the block is made. Since some of our trouble has been because block were used too soon, perhaps we should require that no block leave the manufacturer's yard until 28 days after being made. Now that you know our problem, I should appreciate any suggestions that will be helpful in its solution.

Mr. Harris. W. R. HARRIS.—Do you license concrete products plants in Indianapolis?

Mr. Schulz. MR. SCHULZ.—Not at present, but it is being considered as a part of our proposed ordinance.

Mr. Davis. H. A. DAVIS.—I believe I can say on the part of the manufacturers who are attending this convention that we are glad of the opportunity of assisting the Building Commissioner of Indianapolis with his problem, for we feel that he is sincere in trying to make a just and good code or else Mr. Schulz would not be here. Now, to my mind in general an ordinance should state straight out what the quality of the product should be and where it can be used; also, to express clearly the rights of the city with respect to inspection and rejection and if registration or licensing is required, what the terms and penalties shall be. Often there are written into ordinances other features for the purpose of aiding in obtaining results. To specify how the product must be made would be such a feature. I sincerely hope that the new ordinance for Indianapolis will not tell the manufacturer how to make products, because to do so would be erecting a barrier against ingenuity and individual progress. Ordinances once written are changed only at long intervals, while methods of making concrete are changing almost daily.

Mr. Gaston. H. F. GASTON.—Applying Mr. Davis' line of thought still further. Where an ordinance restricts the manufacturer from shipping his product before it has reached a certain age, such as 28 days, this immediately restricts improvement in curing or hardening of products. In other words, the manufacturer who has installed a very modern steam curing system must hold his product in inventory just as long as he who sets his product out of doors to harden by the most crude method. When the age at which the product can be used is not specified, there remains no reason for requiring a block to be marked with the date on which it is made. What the commissioner really wants to know is that when the block leaves the manufacturer's yard it complies with the requirements of the ordinance pertaining to quality.

Mr. Bliss. MR. BLISS.—Perhaps a description of the working of our New York ordinance with respect to licensing of plants may be of interest to Mr. Schulz. When a man on Long Island wishes to start selling block, he applies for a license. Some block must be sent in for testing. If the manufacturer wishes to be dishonest, these block are made better than those regularly sold. When the license is granted the manufacturer is assigned an initial which he is required to stamp on the block. Sometime afterwards by inspection his block may be rejected on some job and his license revoked. But does this put him out of business? I should say not. Mr. Manufacturer merely takes out a new license in some other name, perhaps the name of some man working for him, and keeps on selling block. It would seem that there should be a better way to handle this problem either in the ordinance or in its enforcement.

MR. LOWELL.—A while ago I said we had representatives from two cities. I believe that Mr. Wilson, representing the Building Commissioner of Detroit, can give us some interesting information, for the Detroit Building Department seems to have a system which produces good results. Mr. Lowell.

J. P. WILSON.—Our Detroit code follows very much the general lines described by Mr. Davis and gives the commissioner's office considerable latitude in issuing licenses. We believe that under any ordinance, best results are obtained by intelligent enforcement. Therefore, we do not issue licenses promiscuously. Before a license is given, we inspect the plant to determine if it is built and equipped so that a satisfactory product can be made. The aggregates used in the plant are tested. We then watch the product as it is being made and finally collect our own samples of the finished product and test them. If everything is satisfactory, the license is issued; if not, we make suggestions for improvement in the plant, materials or process of operation. Not until these suggestions are carried out is the license issued. Mr. Wilson.

Our inspectors who are notified of all construction work under permit make the rounds continually inspecting materials and workmanship. Whenever they are suspicious of any concrete block found on a job, they report to the central office and we take samples for testing and afterwards act accordingly, not only as to the particular material in question, but also the manufacturer of the material. When a manufacturer is licensed we do not forget him entirely. Our central office inspector, who is continually interested in all the manufacturers in our city, makes it a point to call around every now and then, sometimes taking samples for testing. When a manufacturer becomes an offender, his license is revoked and he then has to convince us that his intentions are to comply with the ordinance before another license is issued for that plant.

We have one other class of block maker, the man who makes block only for his own building. Obviously we cannot issue a license to this class, but we keep track of his activity. Since we require the builder in all cases to file the name of the manufacturer of the block to be used, we can immediately tell whether it is made in a licensed plant. When made by the individual for himself, we test samples of the block before a permit is issued for their use.

The popularity of the concrete building product has increased tremendously under this system and the manufacturers seem to be very well satisfied.

MR. HARRIS.—Do you require that the block be marked for identification? Mr. Harris.

MR. WILSON.—Marking has not been required in the past, but the manufacturer as well as we have seriously been thinking it desirable since lately some inferior block are being shipped into the city from other districts. Mr. Wilson.

TENTATIVE RECOMMENDED PRACTICE AND STANDARD SPECIFICATIONS FOR CONCRETE FUEL OIL TANKS.*

GENERAL CONSTRUCTION REQUIREMENTS.

Concrete tanks are recommended for the storage of fuel oil when the specific gravity of the liquid is heavier than 35 degree Baumé at 60 degree Fahrenheit, but should not ordinarily be used for lighter oils.

Fuel oil tanks should be located so as to decrease the fire hazard to a minimum. Their design, location and equipment must be considered from several viewpoints; that of the owner, the insurance underwriter, the Municipality in which they are to be built, the oil-burner and equipment company making the mechanical installation and that of the engineer having charge of the design of the complete layout.

The owner selects a site, preferably for economic use of space in handling the fuel oil. If tanks are to be buried, he determines what load the roof shall carry. He also determines the capacity of the tank or tanks to insure storage of sufficient oil for consumption over a specified period of time.

The insurance underwriters take into consideration the fire hazard presented by each individual installation, and advise the owner as to the capacity allowed under the conditions proposed, and as to the acceptability to them of the proposed pumping and piping layout. They also require certain safety appliances which may or may not have been embodied in the plans of the equipment company.

The Commonwealth or Municipality or Metropolitan District may have regulations governing the storage of fuel oil. If there are such regulations, the approval of the officials in charge must be obtained, and when obtained it sometimes becomes necessary to obtain building permits from the proper authorities.

The oil burner and equipment company usually designs the supply and feed piping, the pumps, the safety appliances, determines their location and the location of the fittings in contact with the tank, installs heating coils for raising the temperature of the oil for pumping where required, and in general does all of the detail work pertaining to the mechanical installation of the system.

A competent experienced designing and constructing concrete engineer, satisfactory to or representing the owners should be responsible for the

*Prepared by Committee S-4, on Concrete Storage Tanks of the American Concrete Institute—February 1920; Revised 1921 and 1922. Accepted by Annual Meeting, January, 1923.

design of the concrete tank, should inspect its construction, especially during the placing of the concrete, and should have authority to harmonize the different interests.

Care should be taken in the design to provide for all external and internal stresses; namely, hydrostatic pressure of contents, external hydrostatic pressure from the ground upon the floor and walls, earth pressure on walls, and live and dead load on roof.

In continuous or restrained members, positive and negative bending moments should be given equal consideration. Temperature reinforcement should be placed in the walls and floor independent of other reinforcement, the steel ratio being not less than one-third of one per cent. The maximum range in temperature should be predetermined as a basis of calculation.

While the hydrostatic pressure of water in soils is about 50 per cent of the full hydrostatic pressure, it is recommended that not less than 52½ lb. per sq. ft. for the full head of water be assumed and allow the difference as a factor of safety for unforeseen conditions.

Steel in tension, whether in circumferential tension or in tension due to negative bending moments on the face of tank walls or floor exposed to the oil, should be designed for a safe working stress of 10,000 lb. per sq. in. In circumferential walls, the thickness of the concrete should be based upon a maximum tensile strength in the concrete of 150 lbs. per sq. in., but a minimum thickness of 8 in. at the top and 10 in. at the bottom of walls is recommended to give space for spading. Working stresses in the concrete or steel not otherwise covered should conform with the recommendations of the current report of the Joint Committee on Concrete and Reinforced Concrete.

All tanks should be built with a concrete roof. The roof should be made gas-tight at the junction with walls, and should be constructed without unprotected openings.

At least two manholes should be provided for each tank 20 ft. in diameter and over and one manhole for tanks of lesser diameter. The multiplicity of manholes is recommended so that oil vapors or gases may be more quickly diffused when the tank is opened prior to being cleaned out and other work being done within.

Fittings for pipe connections and attachments to hold heating coils should be placed where shown on the plans.

The tanks should be set on firm, well tamped earth, rock or other suitable foundation to guard against settlement. The foundations should be constructed to provide full bearing for the tank bottom.

In order to carry out the recommendations contained herein, the service of competent engineers and engineering contractors experienced in this work are required in making the design and specifications and in superintending the construction.

REINFORCEMENT

Specifications:—The reinforcing metal should meet the requirements of the current standard specifications for billet steel reinforcement of

the American Society for Testing Materials excepting that twisted square bars should not be employed in the construction. Reinforcing should be free from excessive rust, scale, paint or coatings of any character which would tend to reduce or destroy the bond.

Splicing:—Wherever it is necessary to splice the reinforcement, no lap-splice should be less than forty (40) diameters. No two laps of adjacent rods should be directly opposite each other in circular walls.

Placing:—Reinforcing steel should be cleaned of all mill and rust scales before being placed in the forms. All reinforcement should be bent or curved true to templates, placed in its proper position as required by the plans and securely wired or fastened in place, well in advance of the concreting. Reinforcement should be inspected and approved by the engineer before any concrete is deposited.

CONCRETE SPECIFICATIONS.

MATERIALS.

Cement:—The cement should meet the requirements of the current standard specifications for portland cement adopted by the American Society for Testing Materials and this Institute (Standard No. 1). It should be stored in a weathertight structure with the floor raised not less than one ft. from the ground. Cement that has hardened or partially set should not be used.

Aggregate:—Before delivery on the job, the contractor should submit to the engineer a fifty (50) lb. sample of each of the aggregates proposed for use. These samples should be tested and if found to pass the requirements of the specifications, similar material should be considered as acceptable for the work.

Fine Aggregate:—(a) Fine aggregate should consist of natural sand or screenings from hard, tough crushed rock or pebbles clean and free from any surface film or coating and graded from fine to coarse particles passing, when dry, a sieve having four (4) meshes per lin. in. Fine aggregate should not contain injurious vegetable or other organic matter as indicated by the Colorimetric Test, nor more than seven (7) per cent by volume of clay or loam. Field tests may be made by the engineer on fine aggregate as delivered at any time during the progress of the work. If there is more than seven (7) per cent of clay or loam by volume in one (1) hour's settlement after shaking in an excess of water, the material represented by the sample should be rejected.

Colorimetric Test:—(b) The Colorimetric Test may be applied in the field as follows: Fill a twelve (12) oz. graduated prescription bottle to the four and one-half ($4\frac{1}{2}$) oz. mark with the sand to be tested. Add a three (3) per cent solution of sodium hydroxide until the volume of sand and solution, after shaking, amounts to seven (7) oz. Shake thoroughly and let stand for twenty-four (24) hours. The sample should then show a practically colorless solution or at most a solution not darker than straw color.

Coarse Aggregate:—Coarse aggregate should consist of clean, hard, tough crushed rock or pebbles graded in size, free from vegetable or other organic matter and should contain no soft, flat or elongated particles. The size of the coarse aggregate should range from one (1) in. down, not more than five (5) per cent passing a screen having four (4) meshes per lin. in. and no intermediate sizes should be removed.

Mixed Aggregate:—Crusher-run, stone, bank-run gravel or mixtures of fine and coarse aggregates prepared before delivery on the work should not be used because the ratio of fine to coarse material varies so widely as to lead to concrete mixtures of greatly varying proportions.

Water:—The water should be free from oil, acid and injurious amounts of vegetable matter, alkali or other salts.

PROPORTIONS.

Unit of Measure:—The unit of measure should be the cu. ft. Ninety-four (94) lb. (one sack or one-fourth barrel) of cement should be assumed as one cu. ft.

Proportions:—The concrete should be mixed in a proportion by volume not leaner than one (1) sack of portland cement, one and one-half (1½) cu. ft. of air dry or the equivalent of fine aggregate and three (3) cu. ft. of coarse aggregate.

> *Note:*—The proportion of fine aggregate should be on the basis of air-dried material because of the bulking of damp sand.

Measuring:—The method of measuring the materials for the concrete, including water, should be one which will insure separate and uniform proportions of each of the materials at all times.

MIXING.

Machine Mixing:—(a) All concrete should be mixed by machine in a batch mixer of an approved type equipped with suitable charging hopper, water storage and a water measuring device which can be locked.

(b) The ingredients of the concrete should be mixed to the required consistency and the mixing continued not less than one and one-half (1½) min. after all materials are in the mixer. Including water, and before any part of the batch is discharged. The mixer should be emptied before receiving materials for the succeeding batch. The volume of the mixed material used per batch should not exceed the manufacturer's rated capacity of the drum.

(c) In no case should aggregates containing frost or lumps of frozen material be used.

(d) The mixing plant should be of sufficient capacity and power to carry out each prearranged operation without danger of delay during the process.

Consistency:—The quantity of water used in mixing should be the least that will produce a plastic or workable mixture which can be worked into the forms and around the reinforcement. Under no circumstances should the consistency of the concrete be such as to permit a separation

of the coarse aggregate from the mortar in handling. An excess of water should not be permitted as it seriously affects the strength of the concrete and any batch containing such an excess should be rejected.

Retempering:—The retempering of mortar or concrete which has partially hardened, that is, remixing with or without additional materials or water, should not be permitted.

DEPOSITING.

General:—(a) Before beginning a run of concrete all hardened concrete or foreign material should be completely removed from the inner surfaces of all conveying equipments.

(b) Before depositing any concrete, all debris should be removed from the space to be occupied by the concrete, all steel reinforcing should be secured in its proper location, all forms should be thoroughly wetted except in freezing weather unless they have been previously oiled and all formwork and steel reinforcing should be inspected and approved by the engineer.

Handling:—Concrete should be handled from the mixer to the place of final deposit as rapidly as possible and by methods of transportation which would prevent the separation of the ingredients. The concrete should be deposited directly into the forms as nearly as possible in its final position to avoid rehandling. The use of chutes is not recommended. The piling up of concrete material in the forms in such manner as to permit the escape of mortar from the coarse aggregate should not be permitted. Under no circumstances should concrete that has partially set be deposited in the work.

Depositing:—(a) Where continuous placing of concrete in floor and walls is impracticable, the operations should be in the following order:

1. The concrete of footings and floor.
2. The concrete of walls.
3. The concrete of columns, if any.
4. The concrete of the roof.

(b) No break in time of over forty-five (45) min. should occur during any one operation except between columns and supported roof slabs where six (6) hours should elapse to permit the settlement of concrete in the columns. In placing concrete in floors, it should not be allowed to set up on exposed vertical faces where work is temporarily discontinued. Column footings should be placed monolithically with floor and the floor reinforcement so designed as to distribute the column load over a sufficient area.

(c) In walls the concrete should be placed in layers or not over twelve (12) in. for the entire wall so that a monolithic structure will result. The concrete should be thoroughly worked around the reinforcing material so as to completely surround and embed the same.

(d) If the placing of concrete is unavoidably interrupted by acci-

dent or otherwise, the previous surface should be roughened and washed clean with a hose, a mixture of 1 : 1 mortar slushed on uniformly before further concreting is done and the new concrete deposited immediately thereafter.

(e) When deposited in the forms, concrete should be thoroughly spaded against the inner and outer faces of the forms so that it will densely compact and force out the trapped air and work back the coarser particles from the face of the forms. More and better work can be accomplished by using light wooden sticks one by two in., planed smooth with sheet steel blade at lower end rather than with heavy spades. Enough laborers should be employed, spading *continuously* to obtain satisfactory results.

Depositing Concrete During Freezing Weather:—During freezing weather, the stone, sand or water or all three materials should be heated so that the concrete mixture will have a temperature of at least 60 degrees Fahrenheit. After concrete is deposited, precaution should be taken to prevent freezing for at least forty-eight (48) hours. Concreting should not be begun when the temperature is below 15 degrees Fahrenheit.

FINISHING.

The floor and roof should be brought to grade with a straight edge or strike-board, finished with a wood float and troweled to a smooth surface as soon as possible after the concrete is deposited. Voids in walls, if any, should be filled with a one to one and one-half (1: 1½) mortar as soon as the forms are removed. After filling these void spots they should be rubbed smooth with a fine grained carborundum brick.

FORMS.

Material:—The forms should be of good material planed to a uniform thickness and width, tongued and grooved for walls, strongly made and located or held in place by exterior bracing or on the outside of circular walls by circumferential bands so that no distortions allowing displacement of concrete will be possible.

Workmanship:—Joints in forms should be tight so that no mortar will escape. All forms should be oiled and if forms are to be re-used, they should be thoroughly cleaned and re-oiled. (A slush mixture of one-half petrolatum and one-half kerosene makes a good mixture for oiling forms.) The use of bolts or wires through the concrete should be prohibited. All spreaders should be removed.

Removal:—The forms should not be removed until the concrete has sufficiently hardened so that no deflection or damage will result. In warm weather column and wall forms should remain undisturbed for at least forty-eight (48) hours and roof forms at least seven (7) days. In cold weather no predetermined rules can be made, but should be left to the judgment of the engineer in charge.

Sliding Forms:—Contractors equipped to handle the work with sliding

forms may be permitted to do so provided the forms are left at one level until the concrete which will be exposed on raising them has hardened sufficiently to sustain the weight of the concrete above.

DETAILS OF CONSTRUCTION.

Joints:—(a) Unless the roof is insulated against temperature changes by sufficient earth cover or the reinforcing in walls and roof is designed to take care of temperature stresses likely to occur, an expansion joint should be provided between the tops of walls and the bottom of roof slabs so that any expansion of the roof due to temperature changes will not transmit bending moment into the walls.

(b) In roof slabs where temporary stops are necessary, they should be made on the plane of least shear, that is; at the middle of beams or slabs.

(c) If walls and floor are not deposited in one operation an approved joint or dam should be provided between the floor and walls. It can be made as follows: (1) provide a recess in the floor to engage the wall and insert a galvanized iron strip at least ten (10) in. wide with joints riveted and soldered so as to form a continuous band on one side of the recess, or (2) place a ten-in. strip of deformed sheet metal one in. back from the inside form and engaging floor and wall equally. After wall form is removed the 1 in. recess is to be plastered with a 1 : 1½ mortar to make a 6-in. coved base.

Treatment of Concrete Surface:—The interior of the tank should be oil-proofed. This work should be done only by persons familiar with this process. A bond guaranteeing the work for a term of years should be furnished.

> *Note:*—Oil-proofing is deemed essential owing to the possibility of using the tank as a container for oils of various characters.

Water Test:—The tank should be tested as soon as practicable in the opinion of the engineer by filling with water, and should show no signs of leakage during a period of seven (7) days.

Service:—The tank should not be placed in service until after the engineer in charge of the work is assured that the concrete has gained sufficient strength to resist all involved stresses.

Backfilling:—Backfilling should not be done around the walls nor deposited on the roof until after the water test has been made and at such a time when in the opinion of the engineer in charge, it can be safely done.

Protection Against Lightning:—All steel reinforcement should be interconnected and grounded by an approved method as a protection against lightning. Any pipe passing through the tank should be properly bonded to the reinforcement.

Venting of Tanks:—(a) An independent, permanently open galvanized iron vent pipe terminating outside of building shall be provided for every tank. The lower end of the vent pipe shall not extend through the top into the tank for a distance of more than one in.

(b) Vent openings shall be screened (40 by 40 non-corrodible wire mesh or its equivalent, preferably cone shaped) and shall be of sufficient area to permit power inflow of liquid during the filling operation and in no case less than one and one-quarter ($1\frac{1}{4}$) in. in diameter. Screens shall be accessible for examination and removal. Vent pipes shall be provided with weatherproof hoods, and terminate twelve (12) ft. above top of fill pipe, or, if tight connection is made in filling line, to a point one (1) ft. above the level of the top of the highest reservoir from which the tanks may be filled and preferably not less than three (3) ft., measured horizontally and vertically, from any window or other building opening.

Filling Pipe:—End of filling pipe in tank shall be turned up so as to form a trap or seal, and when installed in the vicinity of any door or other building opening shall be as remote therefrom as possible so as to prevent liability of flow of oil through building openings; terminal shall be outside of building in a tight, incombustible box or casting, so designed as to make access difficult by unauthorized persons.

Manhole:—Manhole covers shall be securely fastened in order to make access difficult by unauthorized persons. No manhole should be used for filling purposes.

Oil Level Indicating Device:—A test well or gaging device shall be installed and so designed as to prevent the escape of oil or vapor within the building at any time. The top of the well shall be sealed and where located outside of building, kept locked when not in use,

Pipefitting:—All pipes shall pass through the roof, if possible. If necessary to pass through the walls, there should be flanged sections with a space of about one and one-half ($1\frac{1}{2}$) in. left between the flange and the concrete on each side of the wall; this space should be calked later with litharge and glycerin or other approved oilproof material. It is advisable also to have a ring projecting about two (2) in. around the pipe sleeve which engages the concrete.

Care of Surface Water:—(a) In many cases it becomes necessary to construct reinforced concrete tanks in localities near tidewater, rivers, streams or water basins where water pressure may be derived through porous soils. Care should be taken to keep this water pressure from fresh concrete until it has attained sufficient strength to fully resist the assumed hydrostatic pressure.

(b) If it becomes necessary to sheet-pile or shore the tanks, the shores should be so designed that they will not pass through the walls and thus leave openings that it would be necessary to fill later.

Cleaning Out Tanks: Warning:—It is dangerous to life to enter fuel oil tanks soon after they are opened as there is not only danger of suffocation from oil fumes on account of the absence of sufficient oxygen, but an explosion may be caused by the accidental presence of an open flame in the vicinity. Before entering the tanks should, therefore, be freed from all inflammable vapors.

Report of Committee S-3, on Reinforced and Plain Concrete Sewers and Conduits.

Committee S-3, on Reinforced and Plain Concrete Sewers and Conduits submits herewith an appendix to the "Standard Specifications for Monolithic Concrete Sewers, Reinforced Concrete Pipe Sewers, with Recommended Rules for Concrete Sewer Design, revised in 1920."

At the 1920 convention of the Institute, certain objections were made to the above specifications, in so far as they related to reinforced-concrete pipe, and as a result of this, the Board of Direction appointed two committees, P-7, to deal exclusively with Concrete Pipe, Drain Tile and Conduit, and S-3, with Reinforced and Plain Concrete Sewers and Conduits.

It is suggested that in the publication of this report in the 1923 "Proceedings" of the Institute that all material dealing with reinforced-concrete pipe be eliminated and the specifications be known as "Standard Specifications for Monolithic Concrete Sewers and Recommended Rules for Concrete Sewer Design" (with Appendix).

For the coming year the committee will make a special study of the performance of existing monolithic concrete sewers in various cities of the United States and some foreign countries with particular reference to the permanence, ability to resist erosion and other special features. This study will necessitate a survey of existing sewers and will be the basis for future recommendations on the design and construction of monolithic concrete sewers.

Respectfully submitted,

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TENTATIVE STANDARD SPECIFICATIONS FOR MONOLITHIC CONCRETE SEWERS AND RECOMMENDED RULES FOR CONCRETE SEWER DESIGN.*

Revision of Standard Specifications No. 24.

PART I.—MATERIALS.

Cement.

Section 1. All cement shall conform to the current specifications for portland cement of the American Society for Testing Materials, and shall be tested in accordance with the methods of testing described in the specifications of that Society.

Fine Aggregate.

Section 2. Fine aggregate shall consist of sand graded from fine to coarse and passing when dry a screen having holes one-quarter in. in diameter. It shall be clean, coarse, free from dirt, vegetable loam or other deleterious matter. Not more than 6 per cent shall pass a sieve having one hundred meshes per lin. in.†

Section 3. Fine aggregate shall be of such quality that mortars composed of the proportions of cement and fine aggregate hereinafter specified for the various classes of concrete shall show a compressive strength after fourteen (14) days at least equal to the strength of mortar made of portland cement and standard Ottawa sand in corresponding proportions and of the same consistency‡.

Coarse Aggregate.

Section 4. The coarse aggregate shall consist of crushed stone, gravel or blast furnace slag which is retained on a screen having ¼ in. diameter holes and graded from the smallest to the largest particles. It shall be clean, hard, durable, free from all deleterious matter and soft, flat or elongated particles. Crusher dust in sufficient quantity to weaken the concrete will not be permitted. For reinforced-concrete arches or for plain

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*Accepted by Annual Meeting, January, 1923.

†Crushed stone screenings may be permitted for use as fine aggregate provided that they shall comply with all the specifications of Sections 2 and 3, and further that they shall be produced from stone having a French coefficient of wear of not less than 8, as described in Bulletins No. 347 and 370 of United States Department of Agriculture.

‡It is recommended that, if possible, available fine aggregates be tested before awarding contracts. If it appears necessary to use an aggregate of poorer quality than above specified the proportion of cement in the various classes of concrete should be increased in order that the strength of the mortar actually used shall not be less than that with the Ottawa sand. If, however, the strength of the resulting mortars is less than 70 per cent of those with Ottawa sand, fine aggregate should be rejected entirely.

concrete arches less than 6 in. in thickness, the maximum size of particles shall be such as will pass a screen having 1 in. diameter holes. For inverts and plain concrete arches over 6 in. in thickness, the maximum size of particles shall be such as will pass a screen having 1½ in. diameter holes.

Section 5. Where crushed stone is used it shall have a French coefficient of wear of not less than 8, as described in bulletins No. 347 and 370 of United States Department of Agriculture.

(The above paragraph is for use in locations where limestone or sandstone of a questionable value are common. If all available stone it suitable, the paragraph may be omitted.)

Aggregate

Section 6. Samples of not less than ½ cu. ft. of fine aggregate and not less than one cu. ft. of coarse aggregate shall be delivered in suitable boxes or containers. All samples shall be plainly labeled with the places where taken, where to be used, the date, and the name of the collector.

Section 7. For the purpose of determining proportions of materials for concrete, each bag of cement containing 94 lb. shall be considered as containing one cu. ft. Sand and coarse aggregate shall be measured loose in approved boxes or hoppers.

Water.

Section 8. Water used for concrete shall be free from oil, acid, alkalies, or organic matter.

Concrete Reinforcement Bars.

Section 9. All steel reinforcement shall consist of cold drawn steel wire fabric having an elastic limit of not less than 55,000 lb. per sq. in.; or of expanded metal having an elastic limit of not less than 55,000 lb. per sq. in., and expanded cold from steel sheets; or of reinforcing bars.

9.1. Steel bars for reinforced-concrete sewers shall conform to the current specifications of the American Society for Testing Materials for (A) Billet Steel or (B) Rail Steel, except that rail steel bars may be used in sizes of 1 in. and under only, and hot twisted bars will not be permitted.

Section 10. Dimensions of bars given on the plans are based on square sections. The net area and weights of bars shall not be less than 95 per cent of the values for square bars as indicated. In computing the weights of steel, one cu. in. of steel shall be regarded as 0.283 lb.

Measurement and Payment

Section 11. The quantity of metal to be paid for shall be the number of pounds actually placed, as shown on the drawings as ordered. It shall not include any waste metal due either to the nature of the construction or to the fact that the lengths supplied are too long or too short for their purpose.

The quantity paid for shall, however, include extra metal in laps, where authorized, due to the fact that a single bar would be unreasonably long.

All bars shall be of the length ordered and shall be in one piece where required up to 30 ft. in length.

The compensations shall cover the cost of furnishing and delivering metal, including any royalty, the cutting, bending, placing, fastening in position, coating with cement and all other work and materials connected therewith.

Castings.

Section 12. Circular cast iron frames and covers for manholes and catch basins and any other iron castings shown on the drawings, or specified herein, necessary to complete the work, shall be furnished and placed. **Description**

Section 13. All castings shall be of tough, close-grained gray iron, free from blow-holes, shrinkage, and cold-shuts. They shall be sound, smooth, clean, and free from blisters and all defects. **Cast Iron**

Section 14. All castings shall be made accurately to dimensions to be furnished and shall be planed where marked or where otherwise necessary to secure perfectly flat and true surfaces. Allowances shall be made in the patterns so that the thickness shall not be reduced. Manhole covers shall be true and shall seat at all points. **Workmanship**

Section 15. All castings shall be thoroughly cleaned and painted before rusting begins, and before leaving the shop, with two coats of high-grade asphaltum or other suitable varnish that the engineer may direct. After the castings have been placed in a satisfactory manner, all foreign adhering substances shall be removed and the castings given two additional coats of asphaltum or other varnish as directed by the engineer. **Cleaning and Painting**

Section 16. No casting shall be accepted the weight of which shall be less than that computed to its dimensions by more than five per cent.

Material for Lining Inverts.

Section 17. All vitrified brick shall be uniform in size, and be not less than 8 in. by 4 in. by 2 in., nor more than 10 in. by 4½ in. by 2½ in. in length, width or thickness, respectively. The brick shall be free from lime or other impurities, uniformly vitrified and annealed, and shall have one edge face such that if the brick is laid on a horizontal plane on that face no portion thereof shall be more than ⅛ in. from the plane.

Section 18. Concrete block for sewer lining shall be uniform in size, not more than 18 in. by 12 in. in surface area and not less than 3 in. in thickness. They shall be made of Class "A" or better concrete, as hereinafter specified, in satisfactory molds, and thoroughly cured. They shall have an ultimate compressive strength at 28 days of not less than 2000 lb. per sq. in.

Section 19. Tile liners for inverts shall not be more than 8 in. by 12 in. in surface area, and not less than 2 in. in thickness. The back of the

tile shall be roughened and equipped with lugs or projections for bedding in mortar. They shall be manufactured under the general requirements covering vitrified sewer pipe and shall comply with the standard tests of the American Society for Testing Materials for clay sewer pipe in so far as applicable.

PART II.—CONCRETE FOR MONOLITHIC CONCRETE SEWERS.

Section 20. Concrete shall consist of a mixture of cement, fine and coarse aggregate and water of the qualities hereinbefore specified.

Concrete shall be of three classes, proportioned as follows:

Class	Cement	Fine Aggregate, cu. ft.	Coarse Aggregate, cu. ft.
A..............................	1 sack	2	4
B..............................	1 "	2½	5
C..............................	1 "	3	6

Mixing

The relative proportions of fine and coarse aggregates may be modified at the direction of the engineer, provided that the proportions of cement to the total of the aggregates measured separately shall not be changed.

Section 21. Concrete shall be machine mixed. The concrete mixer shall be designed to take one completed batch of materials (using whole bags of cement) and to mix that batch thoroughly before any portion of it is withdrawn or any portion of the succeeding batch is introduced. The mixer shall be equipped with a tank so designed that when once set it will automatically supply to the mixer the amount of water so determined. The mixer shall be equipped with an instrument for measuring the time of mix.

Section 22. Concrete shall be mixed at least one minute after all the ingredients, including water, have been discharged into the mixer. Where the character of the work will permit, concrete shall be mixed in batches of one-half to one cu. yd. and the mixer speed shall not be less than 12 nor more than 19 revolutions per minute. Where small mixers are used, the speed shall not exceed 22 revolutions per minute.

Section 23. No concrete shall be hand-mixed except relatively small quantities, and then only by special permission of the engineer.

Section 24. Where concrete is mixed by hand, the cement and fine aggregate shall be mixed dry on a properly constructed wooden or steel platform built for the purpose until it shall have obtained an even and uniform color throughout. The mixture shall then be spread to make a bed of uniform thickness, on which shall be spread the coarse aggregate and the whole wet with the required amount of water and turned with square-pointed shovels at least three times or until a uniform mixture is secured, water being added from time to time, if necessary.

Rubble or Stone in Concrete

Section 25. In all plain concrete, where the thickness is 15 in. or more, there may be embedded broken pieces of sound stone, the greatest dimension of which does not exceed 6 in., and the least dimension of which is not less than three-quarters of the greatest dimension. These stones shall be set in the concrete as layers are being rammed, in a satisfactory manner, and so placed that each stone is completely and perfectly embedded. In general, there shall be a space of 4 in. between the stones and no stone shall come within 4 in. of any exposed face. The stone shall be thoroughly cleaned and wet before placing.

Consistency

Section 26. In mixing concrete, it is advisable to use the least possible amount of water required to obtain a workable mix, and when the aggregate is dry, 6 gal. of water to a sack of portland cement is the maximum which should be used. (For slag aggregate this may be somewhat increased.) Where comparatively dry mix is to be used, as in inverts, and near the crown of the arches, the concrete must be thoroughly tamped until the water flushes to the surface.

Work in Freezing Weather

Section 27. Concrete shall not be mixed nor deposited in the work in freezing weather except as directed. If the work on concrete structures is prosecuted in cold weather, proper precautions shall be taken for removing ice and frost from the materials, including heating the water and aggregates; for protecting the newly-laid masonry from freezing, and for securing work satisfactory in all respects. Satisfactory covering for the newly-laid concrete and such additional appliances and materials as may be required therefor, including steam pipes for keeping the air warm beneath the said covering shall be provided.

Transporting and Placing Concrete.

Transporting

Section 28. Provision shall be made for quickly transporting the concrete from the mixer to the work and with as little shaking as possible, so that the tendency of water to rise to the top may be reduced to a minimum. Any concrete which may have been compacted during transportation shall be satisfactorily remixed before being placed in the work. Any concrete delayed one-half an hour in transit shall not be used in the work and must be removed from the premises.

Placing Concrete

Section 29. Concrete shall be deposited so as to maintain a nearly level surface and avoid flowing along the forms. It shall be continuously and sufficiently worked to expel air and to force the aggregate away from the forms. In special cases, as where concrete is deposited on slopes, a comparatively dry mixture may be used, but great care shall be exercised to spread such concrete evenly in layers not more than 6 in. in thickness and to ram it thoroughly. In general, the methods used shall be such as to give a compact, dense and impervious concrete with a smooth surface.

Joining New Work to Old

Section 30. For the proper bonding of new and old concrete, such provisions shall be made of steps, dovetails, or other devices as may be required. Whenever new concrete is joined to old, the contact surface of the old concrete shall be thoroughly cleaned, using a stiff brush and a stream of water, if required, and shall be clean and wet at the moment the fresh concrete is placed. Where ordered, a thick wash of rich mortar shall be run over the contact surface of the old concrete. Where it is of importance that the joint between the new and old work shall be as strong and tight as possible, especial precautions shall be taken, such as picking off the top one or two in. of the old work so as to remove the laitance or washing the old cement off the surface with acid or alkali and later with water to remove all traces of them, or both, as may be required.

Finish of Concrete Surfaces

Section 31. Special care shall be taken that all concrete surfaces shall be smooth and free from indentations or projections. All surfaces shall be free from voids, exposed stones and other imperfections. If such imperfections are found upon removing the forms, the faults shall be corrected at the contractor's expense by filling with mortar or otherwise, as directed, even to the extent of taking down and replacing unsatisfactory concrete.

Plastering of Concrete Surfaces

Section 32. No plastering of any concrete surface shall be done unless expressly permitted and if so permitted shall be done in strict accordance with directions. No payment will be made for plastering done to correct defective work.

Masonry not to be Laid in Water

Section 33. No concrete or other masonry shall be deposited under water without permission and then only in accordance with directions. Water shall not be permitted to rise on any masonry until the mortar shall have set at least 12 hours.

Forms.

Forms

Section 34. There shall be provided suitable collapsible centers or forms with smooth surfaces of ample strength and rigidly braced. The bracing shall be adequate to prevent deviations from the correct lines.

Section 35. All steel forms shall be neatly and accurately made with all similar parts in each longitudinal section of form interchangeable with other sections. Bent plates required to fit shall be rolled and fabricated to the correct curves before assembling. Suitable forms shall be provided for bends in the sewer. Steel filler plates shall be furnished.

Section 36. All wooden forms shall be built of clean, sound lumber, reasonably free from knots, dressed on all sides of uniform thickness and neatly fitted. Tongued and grooved material shall be used where required. The form surface shall be watertight, securely fastened to the ribs or supports.

Section 37. No forms built up in the trench or ribs with separate pieces of wooden lagging, piece by piece, will be allowed except for specials or curves.

Section 38. No center or form shall be used which is not clean and of proper shape and strength and in every way suitable. Before placing concrete or reinforcement the forms shall be coated with vaseline, form grease or other suitable approved substance, to prevent adherence of concrete.

Placing Reinforcement.

Placing Concrete

Section 39. All steel reinforcement shall be placed in the exact positions and with the spacing shown on the drawings or as ordered, and it shall be so fastened in position as to prevent displacement while the concrete is being deposited.

Shaping and Splicing

Section 40. The reinforcing steel shall be bent to the shapes shown on the drawings or as required. The ends of the bars shall be bent or hooked over if required. The length of the laps for bonding the adjacent bars shall not be less than thirty times the diameter of the bar, when the steel is designed for working stress of 12,000 lb. and not less than forty times the diameter of the bar when the steel is designed for working stress of 16,000 lb. per sq. in. Where the bars are of different sizes, the diameter of the larger bar shall be used.

Storing

Section 41. Steel must be stored in such manner that its condition will at all times correspond to that under which the samples were taken.

PART II-A.--GENERAL CONSTRUCTION, MONOLITHIC SEWERS.

Width of Trench

Section 42. Below the springing line for such sewer, the trench shall be accurately shaped to the form of the outside of the masonry and the concrete shall have a firm bearing on the natural soil or rock at all points below the springing line.*

Section 43. In general the width of the trench for sewers of the horseshoe and similar types shall be one ft. greater than the outside width of masonry to allow for satisfactory bracing.

Underdrain

Section 44. Underdrains of agricultural tile laid in gravel or crushed stone, shall be constructed of the size, and where directed, for the purpose of keeping the work free from water during construction, such drains to be abandoned when the work is completed; underdrains so laid shall lead to sumps or manholes, and water flowing to them shall be removed by pumping. Such pumping shall be carried on continuously, day and night, and the level of the ground water shall be maintained below any cement or concrete which may be placed in the work for a period of at least twelve hours after such cement or concrete is placed. When the temporary underdrains above described are abandoned, they shall be cut and plugged where directed and the sump holes above described shall be solidly filled with approved material.

Construction of Inverts

Section 45. On all sections having a comparatively flat invert, the complete invert shall first be built, while on all circular sections a center strip of not less than one-fourth circumference shall be built. The invert or center strip shall be placed in sections of not over 16 ft. where the surface is to be finished with end guides and a longitudinal straight edge, and not more than twenty ft. if a separate lining of vitrified brick, tile or concrete block is to be provided.

Finish

Section 46. A granolithic finish shall be applied to the fresh concrete as soon as the condition of its surface will permit. This finish shall consist of a mixture of one part of cement to two parts of granite, or other hard rock chips, graded from ⅛ in. to ½ in. in size, and shall be laid 1½ in. thick. The upper surface shall be formed by means of screeds and shall be floated and troweled to a smooth surface. As soon as this surface is dry enough to receive it, a dry mixture of two parts of cement and one part of sand, free from crusher dust and particles larger than ⅛ in. shall be sprinkled over it and then the surface shall be floated and troweled. This treatment shall be repeated at least once, and where the proportion of very fine material in the aggregate necessitates it, a total of three dryer coats shall be applied. Where the placing of the dryer coat must be deferred until the day following the pouring of the concrete invert, the concrete shall be first moistened and covered with neat cement, which shall be thoroughly broomed into the concrete in the form of a thick paste.

Lining (Alternate to Sec. 46)

*Section 47.** Where required, the inverts shall be lined with concrete block, tile, or vertical brick, as shown on the plans.

Block Lining

47.1. The concrete bottom shall be accurately shaped up to a line one-half in. below the bottom of the lining and allowed to set before the lining is laid.

A mixture made of one part of portland cement and three parts of sand, without the addition of water, shall be spread on the finished surface to the depth required to bring the block or brick to the required grade. The lining units shall be laid in straight lines and in a workmanlike manner and so that all joints shall be broken. After being laid, it shall be rolled with a hand-roller weighing from 300 to 500 lb. or tamped until every unit shall have a solid bearing and the top of the finished work shall present a smooth and even surface and conform accurately with the shape of the invert as shown on the plans. The joints between the units shall be grouted with mortar made of one part portland cement and two parts sand and the surface shall be brushed until every joint is completely filled.

Tile Lining

47.2. Where vitrified tile is used, the units shall be carefully bedded in wet mortar, the mortar bed to be approximately ½ in. in thickness.

Protection

47.3. The bottom must be kept free from water until the work is completed and no water will be allowed to run over the completed work until it shall have set.

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*Where there is a probability that wet ground will make the shaping of circular inverts impossible, an alternate section of a suitable type shall be used.

Section 48. The unfinished surface of the invert on which the concrete of sidewalls or arches is to be placed, shall be made as rough as possible. In unreinforced work, dovetails shall be formed as provided in Section 31. In reinforced work, where projecting bars may interfere with the formation of dovetail joints, the invert concrete shall be thoroughly cleaned by a pressure stream of water or scrubbed and every precaution shall be used to prevent earth or material from the forms falling on the surface after cleaning.

Keeping Concrete Moist

Section 49. Precaution shall be taken to prevent concrete from drying until there is no danger of cracking from lack of moisture. Concrete shall be kept moist for at least one week, unless sooner covered with earth. This may be done by covering of wet sand, burlap, continuous sprinkling or by some other method approved by the engineer.

Section 50. Forms for slabs or very flat arches as in box sections or roofs of special chambers, shall remain in place for at least seven days. No load shall be placed on the concrete for fourteen days, and then only with permission.

Removal of Arch Forms

Arch forms shall not be slackened until the backfilling has been carried to a height of at least one ft. above the top of the arch and tamped. Arch forms shall remain in place for forty-eight hours when conditions are most favorable for the hardening of the concrete and for a longer time, as may be directed during inclement weather, or where unusual conditions exist. Permission for dropping center must be secured for each arch unit.†

Section 51. Backfill, over and around arch sewers, shall be placed as soon as possible after the cement has set. The filling up to a plane 2 ft. above the top of the arch shall be made from the best earth and shall not contain a sufficient amount of large stones as to allow the pieces of stone to become wedged. It should be filled in layers of not over 6 in. and carefully tamped. If the remaining of the backfill is dumped from buckets, the contents of the buckets should not be allowed to fall more than 5 ft. unless the impact is broken by timber grillage. Bracing should generally be removed only when the trench below it has become completely filled and every precaution shall be taken to prevent any large slips of earth from the side of the trench onto or against the green arch. All voids left by withdrawal of sheeting shall be immediately filled with sand, by ramming with tools especially adapted to that purpose, by watering or otherwise as may be directed.

Section 52. During the construction of the sewer, care should be taken that no loose mortar or concrete shall be allowed to remain on the interior surface of the invert. At the completion of the work all débris shall be removed and the invert shall be left clean and smooth.

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*This construction is particularly applicable to sewers having comparatively flat inverts, and is more difficult to carry out with circular sewers.

†For small arches, 6 ft. or less, and under the most favorable conditions, forms may be dropped in 24 hours.

General Note.

No attempt has been made to include herein detailed specifications, for much of the work entered into sewer construction, such as earth and rock excavation, sheeting and bracing, etc.

Statements relating to the responsibility of furnishing materials, performing work and giving directions have also been generally omitted.

No specification has been included in regard to the measurement of materials or the amount of work covered in any particular compensation, other than for reinforcing steel, as it has been considered best to leave these clauses to be worked under the conditions prevailing on the particular piece of work.

RECOMMENDED RULES FOR CONCRETE SEWER DESIGN.

(To accompany the Specifications for Concrete Sewers.)

Plain Concrete Monolithic Sewers

1. Concrete sewers without reinforcement are approved for sizes between 30 and 60 in. mean diameter. Plain concrete sewers between these sizes are to be used only in rock or hard soils. It is recommended that the minimum thickness for a diameter of 36 in. or under should be 5 in. and for a 5 ft. diameter 7 in. with intermediate sizes in proportion. These thicknesses are to be taken as a minimum for circular sewers and used only under favorable conditions.

Reinforced Concrete Monolithic Sewers

2. All sewers near the surface and subject to moving loads or vibration, should be reinforced. For sewers of 6 ft. or less in diameter, it is recommended that the reinforcement be ½ of 1 per cent placed near the inside at the crown, and near the outside at the springing lines.

If it appears at all possible that the horizontal pressures on the sewer might be large, reinforce for reverse stresses.

3. It is recommended that for all sewers greater than 6 ft. in diameter, several possible types of loading be assumed and stresses be calculated on the elastic arch theory. (The methods are indicated in Turneaure & Maurer's "Principles of Reinforced Concrete," or in Metcalf & Eddy's "American Sewerage Practice," Volume I.)

4. It is also suggested that in sewers of greater than 6 ft. in diameter, it may be found economical to adopt a section having a comparatively flat bottom, and an arch with or without intermediate side walls.

5. The minimum thickness of concrete in sections of this type should be 8 in. This is recommended as a factor of safety against poor placing and also to secure warterproof structures.

6. The specifications submitted provide for three classes of concrete. It is recommended that all arches be built of Class "A" concrete and that the inverts be of Class "A" concrete except in rock or very hard soils, where Class "B" concrete may be used.

7. For reinforced work in bad ground, the designer should provide for a raft of Class "C" concrete of from 4 to 6 in. in depth, which is to be allowed to set before the reinforced structure is started. This is advisable

to facilitate good workmanship and particularly to prevent contamination of the concrete around the reinforcement by mud or sand.

8. The distance from the face of reinforcing steel to the face of the concrete in monolithic sewers should be not less than 2 in.

9. In determining dimensions of concrete and reinforcement, the following working stresses should be the maximum used:

(*a*) The maximum workin stress in the steel where structural grade is used should be not more than 12,000 lb. and for intermediate or hard grades, or for cold twisted bars, 16,000 lb. per sq. in.

The maximum working stress in rail steel should not exceed 16,000 lb. per sq. in.

(*b*) The maximum working stresses in concrete are based on the Report of the Joint Committee on Concrete and Reinforced Concrete are about 25 per cent less than the stresses there recommended.

WORKING STRESSES IN POUNDS PER SQUARE INCH.

Aggregate	Class A	Class B	Class C
Granite or trap rock	550	450	350
Gravel or hard limestone	500	400	325
Soft limestone or sandstone (if permitted)	375	300	250

Class "B" concrete is not recommended for use in the sewer proper. Soft limestone and sandstone are prohibited if the accompanying specification is rigidly carried out.

These stresses should be further reduced where construction conditions are likely to be very unfavorable to good workmanship, as in very wet or deep trenches.

10. In all important work, specify that the reinforcement shall be held in place with steel chairs or holders and wire ties.

11. Attention is called to the fact that with sewers having comparatively flat inverts, careful consideration must be given to the distribution of load across the invert. Where soils are likely to be compressible, the weight should be taken as uniformly distributed. The stresses in such inverts should be carefully analyzed, as they are generally more severe than the other parts of the sewer.

It will generally be advisable to provide alternate details of the invert for use in rock cuts, when resting on rock or nearly incompressible soils and for soft or wet ground.

12. Accompanying specifications for monolithic work provide for either a granolithic finish on the invert or for a lining of concrete block, brick or tile. The use of the separate lining should be considered as an additional factor of safety where unsatisfactory construction conditions are likely to affect adversely the quality of workmanship and the strength or density of the finished invert concrete.

APPENDIX A.

(Standard Specifications for Monolithic Concrete Sewers, etc.)

METHODS OF DESIGN AND CONSTRUCTION.

To supplement the standard specification for plain and reinforced-concrete sewers, and the recommended rules for concrete sewer design, the committee has prepared this appendix which is intended to cover briefly the essential points of concrete sewer design and construction, with enough bibliography to indicate sources of information on such subjects.

Cross Sections. One of the first topics to consider is the cross-section. Various types have been built in the United States and abroad. Many of the masonry sewers in this country are of circular cross-section, though some of the older ones are egg-shaped or oval. In recent years several other forms of section have come into favor. The following discussion describes briefly some of the advantages and disadvantages of the principal types.

Circular Section. The popularity of this form over the others is largely due to the fact that it encloses a given area with the least perimeter, thus affording the highest velocity when flowing half-full or full. It also offers economy in masonry, under favorable circumstances, but where the trench bottoms are flat or where piling or timber platforms are necessary this does not hold true, as the arch requires additional support. In combined systems, however, this section is not as advantageous as the egg-shaped, as here the dry weather flow of sewage is small in comparison with the storm-weather flow, and the velocity for the low flow would be less in the circular section. For sewers under 5 ft. in diameter these two sections, the circular and the egg-shaped, are usually preferred to other types.

Egg-Shaped. As just mentioned, in the case of combined sewers the egg-shaped section is preferred by some, from the fact that as the depth of flow decreases, the hydraulic radius remains more nearly constant. This advantage also obtains where there is a sanitary sewer to be constructed in a district of which the population served is small in proportion to that anticipated. To express it in another way, with the egg-shaped section for a given quantity of flow the depth is greater, and the velocity is slightly higher than would be the case with a circular section. This higher velocity also produces better flotation for solid matter which in the circular section sometimes tends to obstruct the flow.

A further advantage of this section is that for the same capacity its horizontal diameter is less than in the circular form, which makes possible its construction in a narrower trench. This, of course, in the case of deep trenches, means a saving in excavation. On the other hand, it

must be remembered that the vertical height is greater than in the circular type. It is more difficult type to construct, owing to lack of stability and liability to crack, and in yielding soil it requires more masonry; at the haunches to support the arch. In good stiff soil or in rock this may not be necessary.

There are several forms of the egg-shaped section. The standard form Fig. 1 was designed in England over half a century ago, by John Phillips,

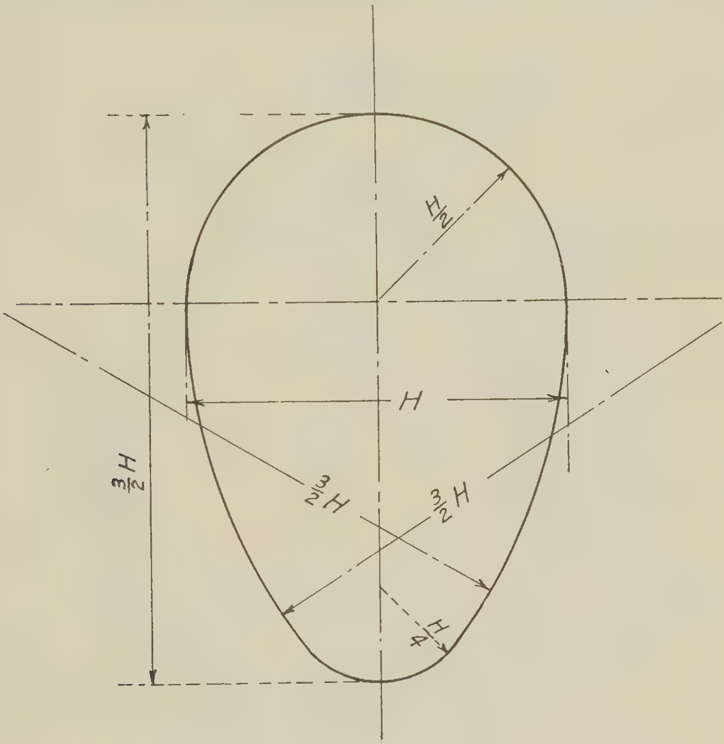

FIG. 1.—PHILLIPS' STANDARD EGG-SHAPE SECTION.

From American Sewerage Practice, Vol. I, by courtesy of the McGraw-Hill Book Co.

and has been popular. Mr. Phillips also designed a modification for use where the normal flow is small in comparison to the maximum, but this has not been so generally used. Other modifications in an effort to afford additional head room or to provide for special variations between the normal and the maximum flows have been made. While some of these forms have found favor abroad, they have been little used here. In gen-

eral the egg-shaped section, while probably as near the ideal from the hydraulic standpoint as any yet devised for variable flows, is somewhat more expensive in general than the circular, and far more so than some of the other types to be described.

Catenary Section. This is primarily advantageous in that it conforms so nearly to the available space inside the wooden timbering in earth tunnels, see Fig. 2. It has also the advantage of strength, its line of resistance

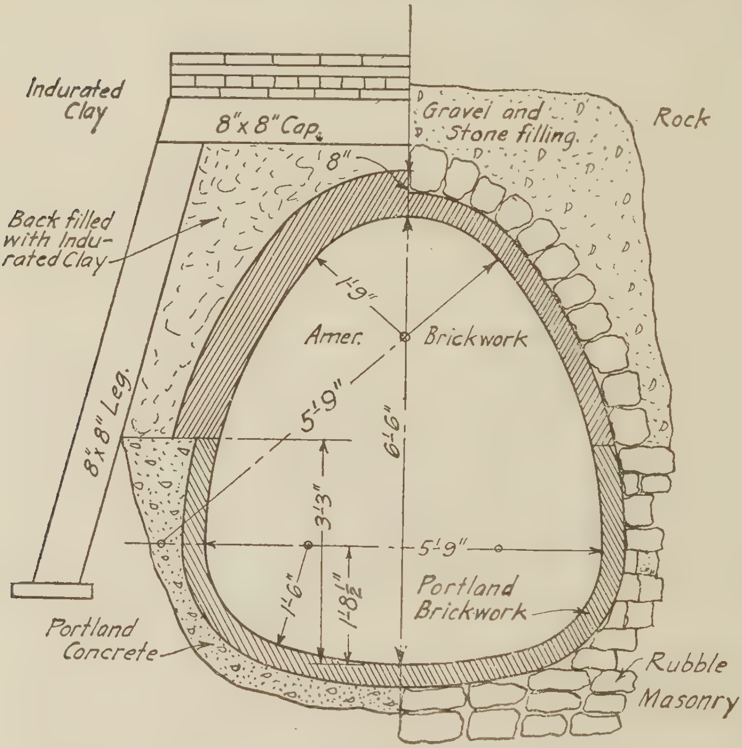

FIG. 2.—TYPICAL CATENARY SECTION USED IN MASSACHUSETTS.

From American Sewerage Practice, Vol. I, by courtesy of the McGraw-Hill Book Co.

lying well within the arch section. Its hydraulic properties are fairly good, and the fact that the center of gravity of the wetted area lies much lower with respect to the height than in the case of the circular section results in the possibility of making lateral connections at a lower elevation or of raising the invert of the main sewer, in cases where it is planned to operate the lateral sewers under a head when the main sewer is running full. In general, however, such a scheme should be regarded with sus-

picion, though it is certainly an advantage where the allowable difference in water level is small. This type will carry a greater quantity for a given increase in depth than the circular sewer.

This type was used extensively on the Metropolitan Sewerage Commission work in Massachusetts, serving the suburbs of Boston, in particular on the North Metropolitan sewerage system under the direction of Howard A. Carson, but of late years its popularity seems to have waned.

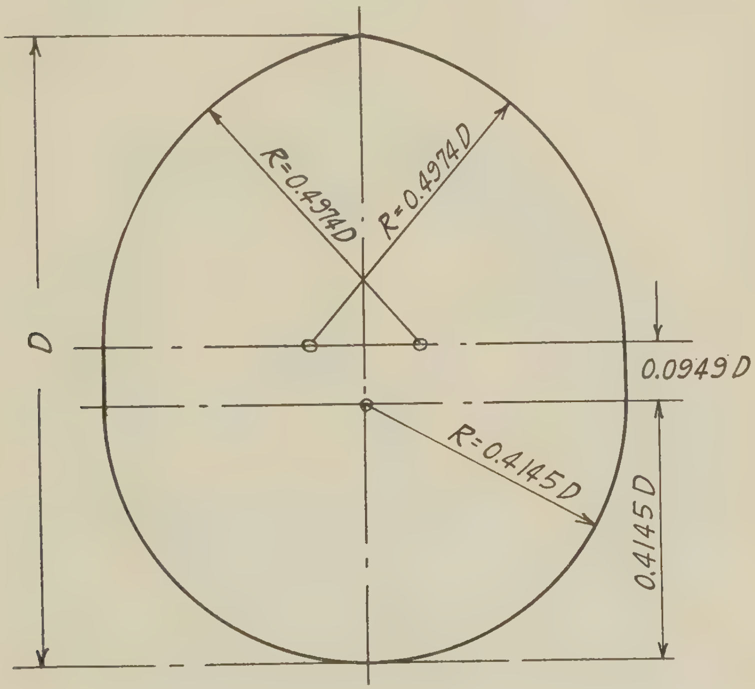

FIG. 3.—TYPICAL GOTHIC SECTION.

Gothic Section. Another section, Fig. 3, used to some extent on the North Metropolitan sewerages system, is the Gothic, which in shape and advantage closely resembles the circular. Its horizontal diameter is about 17 per cent less and its vertical diameter about 8 per cent more than the diameter of the equivalent circle, so that this type requires less width of trench than the circular. Where the sewers are to be located on the basis of the crown grade, however, the greater heights of the Gothic section, necessitating undue excavation, would usually preclude its use. Its hydraulic properties are very similar to those of the circular section and its pointed arch is somewhat stronger than the semi-circular arch. While

this type is not in general use at present, it possesses advantages which justify its consideration for special cases.

The Basket-Handle Section. Fig. 4 is another type extensively used on the North Metropolitan system and also somewhat in other places. Mr. Carson, who developed the section, says of it: *

"The horizontal diameter is about 6 per cent less than the vertical. The arch is slightly pointed and the invert is flatter than a semi-circle.

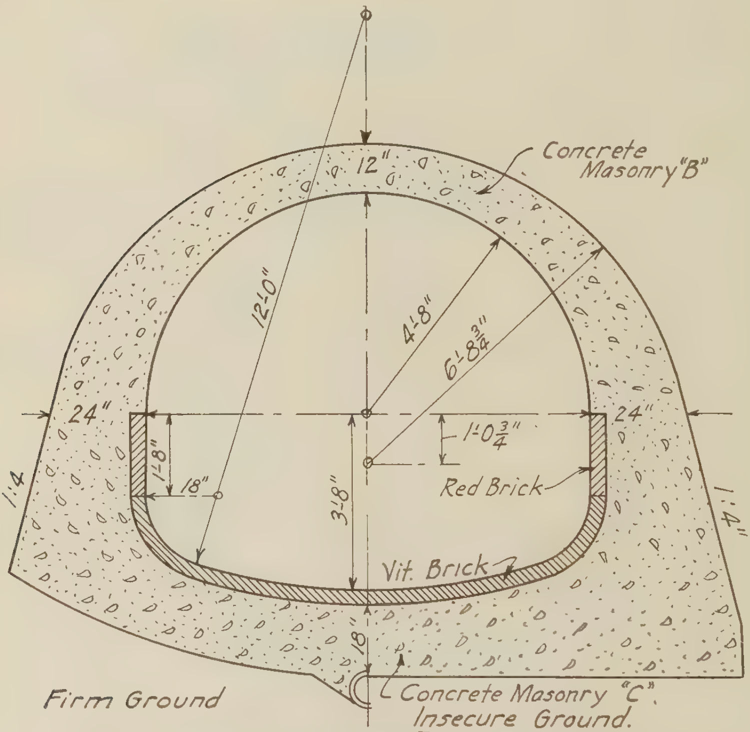

FIG. 4.—TYPICAL BASKET-HANDLE SECTION, WASHINGTON.

From American Sewerage Practice, Vol. I, by courtesy of the McGraw-Hill Book Co.

In this shape the area, perimeter and the theoretical velocity when flowing more than one-sixth full differ but little from the corresponding elements in a circle having the same height. In actual construction, under the conditions that usually obtain on our work, this shape is more stable, when entirely completed, than a circular shape. It requires more care,

*Third Annual Report to the Metropolitan Sewerage Comm., year ending Sept. 30, 1921.

however, to prevent injury to the invert, while the latter is being constructed."

The basket-handle section closely resembles the horse-shoe type next to be described, and has about the same advantages and disadvantages. Its Gothic arch gives slightly greater strength and greater ease in removing the collapsible forms. The large radius curve of its invert and the rounded corners between the side walls and invert may also afford some additional strength, but the horse-shoe type so nearly approximates it in this respect and is so much easier of construction that it is usually used in preference.

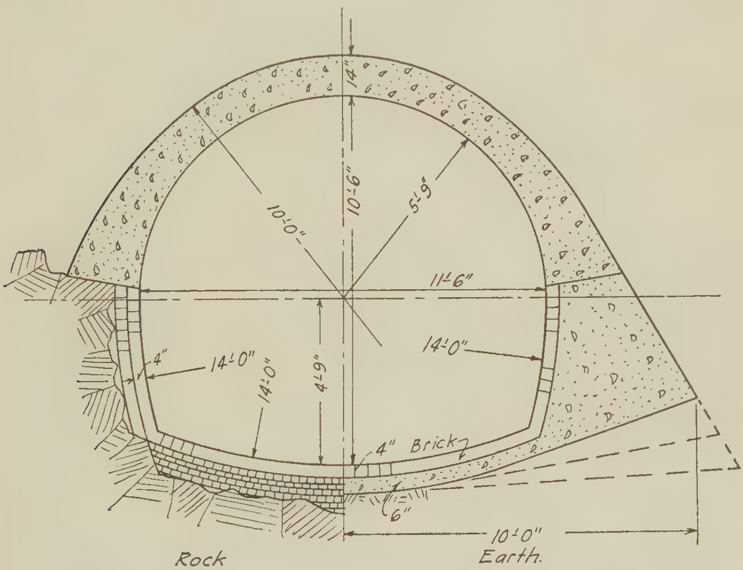

FIG. 5.—TYPICAL HORSESHOE SECTION, WACHUSETT AQUEDUCT.

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The Horse-Shoe Section. Fig. 5, next to the circular, is probably the most popular type. While many modifications have been made, in order to adapt it to special conditions, in general it consists of a semi-circular arch upon side walls inclined inward and having either a plane or a curved surface. The invert surface varies in section from a horizontal line to a circular or parabolic arc and is so constructed as to concentrate the low flow near its center. In yielding soil it has the advantage, over the circular and egg-shaped sections, of conforming to the trench bottom, so that its arch does not require masonry backing. It may also, for a given width, or horizontal diameter, be designed with less height and still carry the same quantity of sewage as the circular section. This decrease in height

would result in a saving in excavation in cases where the depth of the sewer below the surface is controlled by the crown grade. Especially where the head room available is restricted, this wide low horse-shoe type is often advantageous, as it is also in yielding soil where spread foundations are required, as here it affords economy in masonry of the invert. So it

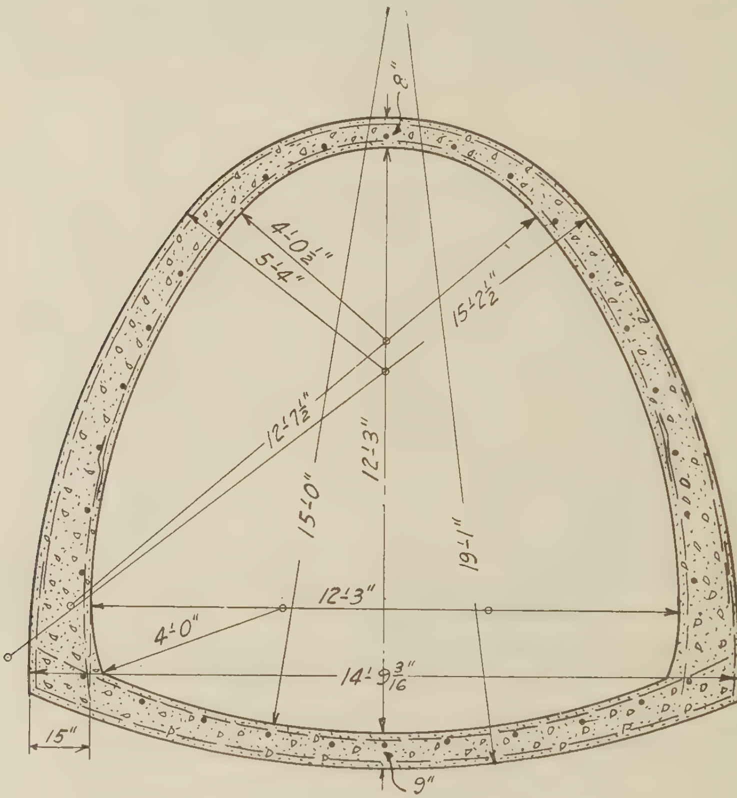

FIG. 6.—TYPICAL SEMI-ELLIPTICAL SECTION, LOUISVILLE.

From American Sewerage Practice, Vol. I, by courtesy of the McGraw-Hill Book Co.

is possible to broaden out and lower this horse-shoe type until the diminishing side walls disappear and the section becomes semi-circular.

Unless this section is built in rock-cut or on an equivalent firm foundation where the invert or base of the side walls will be so supported as to maintain the line of thrust within the section, the whole structure will act as an elastic arch from center of invert to crown, endangering the stability of the arch. To obviate this lateral thrust it is sometimes neces-

sary in compressible soil to make the side walls extremely heavy. The effect of these side walls is to greatly increase the bending moment at the crown and at the center of the invert which will come very severe, especially at the invert center and at the springing line, if the sewer is constructed monolithic of reinforced concrete with the reinforcing bars continuous from center of invert to crown of sewer.

In compressible soil heavy side walls or abutments are also necessary. Reinforcement of the concrete has helped to obviate this trouble, but even in the sections heavily reinforced there have been instances of the arch cracking on the inside of the crown and on the outside at the quarter points or near the springing line. Though failure of the arch did not result in these cases, the condition is objectionable as it permits leakage and possible rusting of the reinforcing steel.

The stability of brick arches in relation to the passive resistance of earth has been discussed by Mr. Alphonse Fteley in a paper entitled "Stability of Brick Conduits" * to which reference should be made by those interested in examples of the effect of yielding abutments on the arch.

The *Semi-Elliptical Section.* Fig. 6, may be either a true semi-ellipse or may be composed of three circular arcs approximating the semi-ellipse. Its chief advantage over the other sections lies in the fact that under working conditions the shape of its arch more nearly coincides with the lines of arch resistance. Hence the arch section can be made relatively thin without creating excessive stresses in the masonry. Unlike the horse-shoe type, this section depends but little on the lateral pressure of the earth, and not at all upon the passive pressure or natural resistance of the earth filling. It also has the advantage over the circular type of a lower, normal flow, since the center of gravity of the wetted area is lower with respect to the crown. Its use is advantageous in earth tunnels, where the usual form of timbering is used, since like the catenary this type conforms readily to the available space.

With respect to the invert, in this type, its stability is more important than the other types thus far discussed, as the arch is so thin in section and extends nearly down to the invert line, making necessary the distribution of the invert pressure over a large area. In cases where the section is constructed in compressible soil and the sewer is monolithic (with steel reinforcing bars running continuously from center of invert to crown of sewer) the invert should be made as thick as the arch, at the springing line, and should be heavily reinforced to resist the large bending moment of the invert center. Otherwise cracqs may occur at this point. The quantity of masonry below the springing line is not excessive in this section, for, like the horse-shoe type, its invert conforms to the trench bottoms.

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*Journal Assoc. Engr. Soc. Feb. 1883.

While the hydraulic properties of this section are in general very good, its wide and shallow invert does not afford as high a velocity during times of low flow, as does the circular section. Where the amount of sewage to be provided for is not liable to wide variations and the normal flow is equal to or greater than one-third of the total capacity of the sewer, this disadvantage may be regarded. In fact, for sewers constructed of reinforced concrete and over 6 ft. in diameter this type is one of the best.

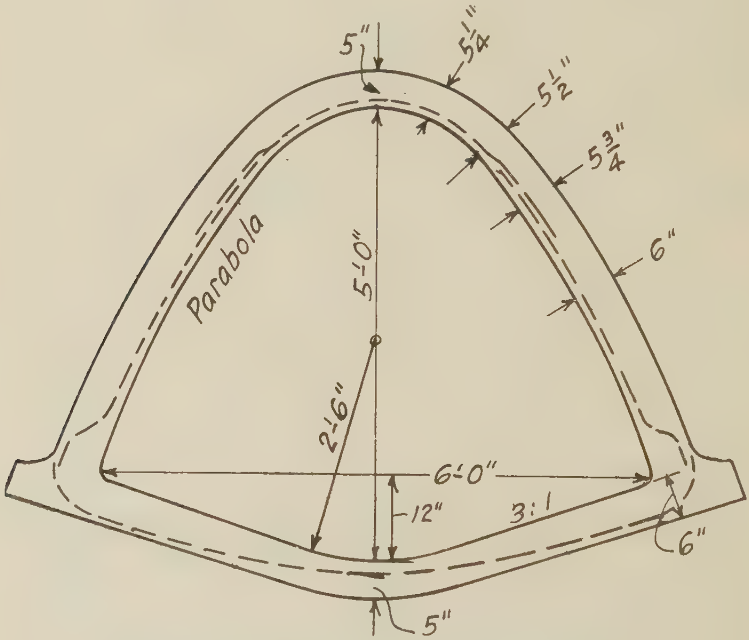

FIG. 7.—TYPICAL PARABOLIC OR DELTA SECTION, HARRISBURG.

From American Sewerage Practice, Vol. I, by courtesy of the McGraw-Hill Book Co.

The *Parabolic, or Delta Section.* Fig. 7, was developed by Mr. James H. Fuertes in designing the sewerage system for Santos, Brazil * and in 1902 he used a similar section for the City of Harrisburg, Pa. This section is nearly triangular, being composed of an arc in the form of a parabola and an invert consisting of a short-circular arc with side slopes of about 3 horizontal to 1 vertical. It may be designed to carry a somewhat greater flow for its height than a circular sewer. In addition to being both economical and strong its sloping invert gives a lower normal flow

*Eng. Record, March 17, 1894.

line than the circular section, which is of value in districts where the available fall is limited, and also in cities where owing to tidal water the sewers must be built in shallow cut. In low land, also, or where there can be but little depth of excavation it offers a further advantage because the greater carrying capacity below the springing line, afforded by the wide invert, makes possible the building of a section of less height than in the case of the circular sewer. This is especially true where the excavation is so shallow that embankment work is necessary.

Of course this section has the disadvantage, over the semi-elliptical type, that its pointed arch requires a relatively wider section for equal capacity and height.

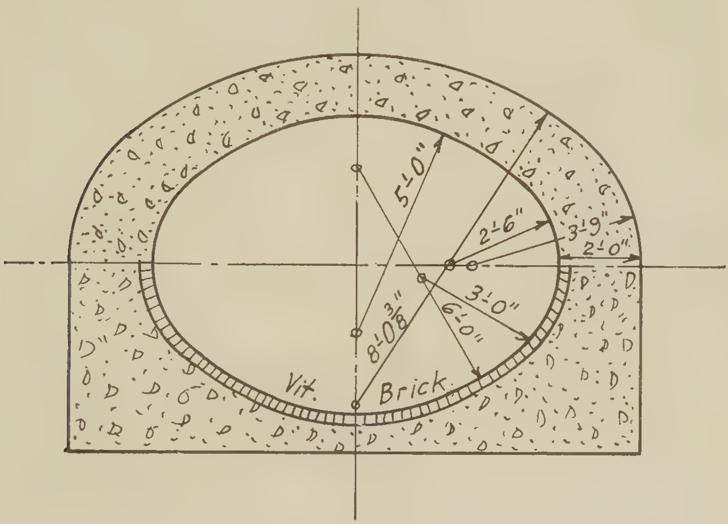

FIG. 8.—TYPICAL ELLIPTICAL SECTION, WASHINGTON.

From American Sewerage Practice, Vol. I, by courtesy of the McGraw-Hill Book Co.

Elliptical Section. Fig. 8, there are a few sewers in this country built with an elliptical section. This section, both above and below the springing line, approximates a portion of an ellipse, the longer axis being sometimes vertical and sometimes horizontal. In general the elliptical section has so little to commend it that it has not proved popular. It has the same disadvantage as was mentioned in connection with the egg-shaped section, that unless it is built in very firm soil additional masonry backing will be needed under the haunches, to support the arch.

The *U-Shaped Section* is used to a limited extent for sewers in the vicinity of 3 ft. in diameter. Undoubtedly it offers some advantage where the width of trench is limited, and where there is sufficient head room

available to build a sewer with the horizontal diameter much less than the vertical. Its hydraulic properties, also, are fairly good though when it becomes filled the hydraulic mean radius is materially reduced due to the addition of the width of the slab roof to the wetted perimeter. Its pointed shape affords greater ease in the removal of forms than is the case with the circular section, and the invert is of such shape that good velocities are obtained at times of low flow.

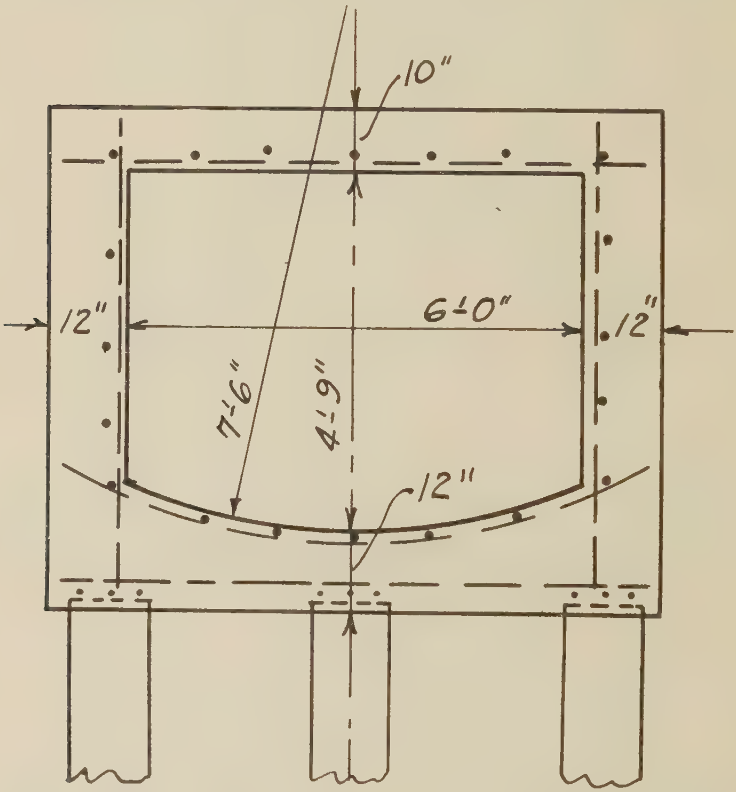

FIG. 9.—TYPICAL RECTANGULAR SECTION, LOUISVILLE.

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The *Rectangular Section*. Fig. 9, has been used for many years to meet special conditions, as where the head room or side room in the trench was restricted. It is easy of construction, economical of space and of masonry, and has good hydraulic properties up to the point where the flat top becomes wet. Just before this point is reached, the velocity and discharge are relatively large, but they decrease rapidly as soon as the wetted

perimeter is increased and the hydraulic radius decreased by the wetting of the top. Hence it is usual in designing these sections to provide for an air space of from 3 to 12 in., above the maximum flow line.

This type is of special advantage in deep rock cuts. The usual form has a less height than width but the hydraulic properties of this section become less favorable as the ratio of height to width increases. There is an advantage in the narrow, high section, as this permits reduction in the width of excavation often sufficient to more than offset the increase in depth of trench.

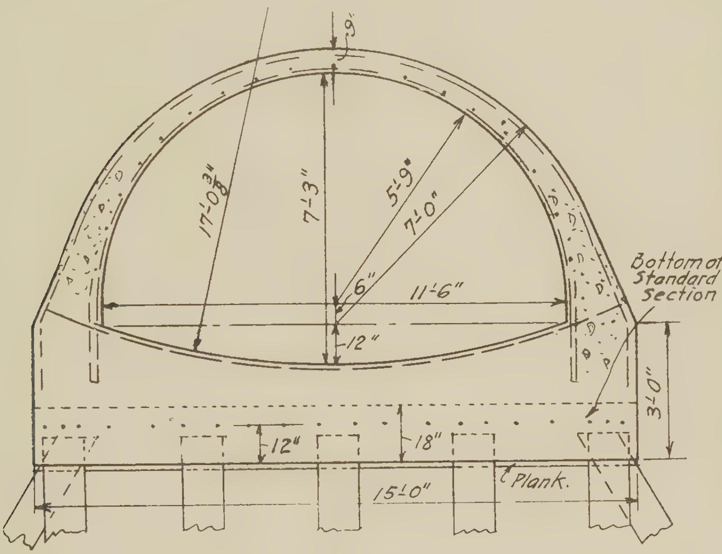

FIG. 10.—TYPICAL SEMI-CIRCULAR SECTION, BRONX.

From American Sewerage Practice, Vol. I, by courtesy of the McGraw-Hill Book Co.

This type of section requires care in design, in order to ensure its stability. If the top is built in the form of a flat slab it must be designed as a beam to provide for the earth load and the side walls must be strengthened to resist lateral pressure. If designed as an arch it is necessary to strengthen the side walls to withstand the thrust.

The flat slab top may be constructed either of I-beams encased in concrete, or as a concrete slab reinforced with bars. The first method, while not economical of steel as the I-beams must take all the load, the concrete merely acting as a filler, is of advantage in that it is possible to complete the sewer and backfill the trench more quickly than where the roof is built as a reinforced slab. Also, the beams are easily and quickly placed, and it is claimed in certain cases this ease of construction offsets

the additional cost. In the case of a large sewer built in a congested district the advantage of speed, permitting prompt backfilling of the trench, may be an important factor. However, the method of construction requires great care to protect the steel from rust.

Quite frequently the rectangular section is constructed with a V-shaped invert, to gain greater velocity for low flows.

Semi-Circular Section. In New York City and vicinity the semi-circular section, Fig. 10, though not as popular as the rectangular, is being

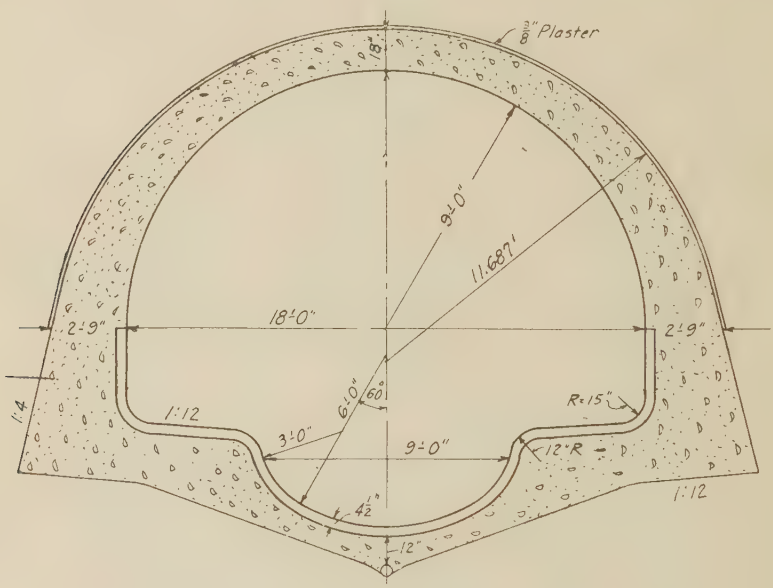

FIG. 11.—SECTION WITH A CUNETTE, WASHINGTON.

From American Sewerage Practice, Vol. I, by courtesy of the McGraw-Hill Book Co.

rather extensively used. Its hydraulic properties are not equal to those of the rectangular section, and it requires a wider trench and more extensive foundations for equal capacity and height, than most of the other types described. Its use is most advantageous for out-fall sewers crossing low lands, where the natural surface of the ground is largely below the top of the sewer arch or even below the invert. The invert must be firm and designed to resist the thrust of the arch. Consequently this type as a rule requires more masonry in proportion to the capacity afforded, than do the other types. In some instances two or more semi-circular sections have been built side by side, in order to save head room.

Double and Triple Sections are especially useful in the case of outfall sewers in thicqly settled districts or where a storm-water sewer is constructed above or below a large sanitary sewer, for the sake of economy in excavation, or head room, or to meet other special problems.

The *Cunette,* Fig. 11, is a special dry weather channel sometimes constructed in the invert of various types of sewers. It has not proven especially popular here, but in France and in Germany has been used extensively. It has the advantage of providing a good channel during times of low flow and thus maintaining self-cleansing velocities. It has the disadvantage of requiring greater depth of trench and additional masonry. One of the notable examples of the cunette in this country is the trunk sewers at Washington, D. C.

Methods of Design. The inside shape of a concrete sewer is often a compromise between the best hydraulic shape, the best shape for structural strength with economy, a shape which is easy to build and conditions of height imposed by head room or hydraulic conditions.

Up to a diameter of 6 ft. a circular shape will frequently meet these conditions satisfactorily. As the size increases, more attention must be given to the shape for structural strength.

In large sizes with flat inverts (dictated by ease of construction) the intensity of soil pressure at any point under the invert requires careful study to determine the thickness and amount of reinforcement. This also will be a factor in deciding whether the sewer is to be analyzed as an elastic ring or the top analyzed as an arch with fixed abutments.

The water in the sewer must be taken into account in determining the stresses on the sewer ring. This is especially important with light cover and heavy eccentric loads. Also conditions during construction or later may occur when the water may exert a bursting pressure and require reinforcement to resist it.

The mathematical methods of sewer arch analysis are given in the textbooks, listed on the attachment.

Economy may be shown by revising the trial sewer shape to make the line of resistance for the normal dead load condition fall within the middle third of the arch ring.

It is usual to specify that the sides of the sewer below the springing line and the bottom are to rest against the undisturbed soil or against the sheeting left in place. While this allows the arch to be supported by the passive soil pressure, it is better practice only to figure on the active soil pressure as some deflection of the sewer or movement of the soil must occur before the passive pressure comes into action.

The design of the sewer section necessitates a study of the conditions under which it is to be built and under which it is to serve. Both live and dead load have to be considered carefully. In large construction, with shallow cover, the live load, as from auto trucks, road rollers, street cars or railroad locomotives, may be extremely important. In deep cover, the

live load is of less importance. Soil conditions also enter in. Hence the importance of trained judgment, especially on the larger problems. In general the horizontal earth load to be used in the design may vary with soil conditions from one-third the vertical load in a relatively stiff soil, to a load in quicksand increasing uniformly with the depth, on a basis of approximately 100 lb. per sq. ft. per ft. depth. This loading is more intense than a water load.

For the surface loadings, allowance must be made according to local conditions. On city streets, street cars and twenty-four ton trucks may need to be provided for. On shallow depth sewers unsymmetrical loadings should be investigated. This has become particularly important because of the increase weight of loaded truck. The loads should be considered from the standpoint of the crowded street, which, of course, lessens the reduction made by any allowance for distribution of load through the earth cover.

Analysis of Stresses. On the smaller sections, say up to 6 ft. internal diameter, practice on uniform soil in different localities has demonstrated in part a reasonable section. However, special conditions may necessitate a thorough analysis of the stresses. On the larger sections, say 6½ ft. and upwards, a special analysis of the stresses is desirable, and particularly so with sections 8 ft. in major dimension and larger. Such analysis can be made along the lines of the elastic theory or the modified method suggested by Metcalf and Eddy (American Sewerage Practice, Vol. I) may be used except where eccentric loadings have to be investigated. In some cases, the old voussoir method of analysis still has application in the study of lines of stress in the sewer ring. The larger the section, the more careful should be the analysis of the stresses and a complete consideration of all details entering in, the condition of the ground, kind of backfilling, with possibility of abnormal stress of unbalanced backfill and the type of loading to be expected.

When the analysis has been made, consideration should be given to future conditions of operation and maintenance. On sewers carrying special industrial wastes or very septic human sewage, or exposed to extremely high velocities, a factor of protection or additional thickness, over the theoretical, may be well worth while.

Standard Sections. In any given locality, where the soil conditions are reasonably uniform, standard sections and thicknesses may readily be worked up. A very good example is Louisville, Fig. 12. Such standardized sections may run in size from tile pipe 6-in. in diameter up to sections with a major dimension of say 6-ft. The dimensions suggested in Fig. 12 are not absolute, as many cities have developed standards with somewhat wider range, even where the soil conditions are not entirely uniform. Such standards will also require occasional adjustment, where special sections are required, for hydraulic reasons.

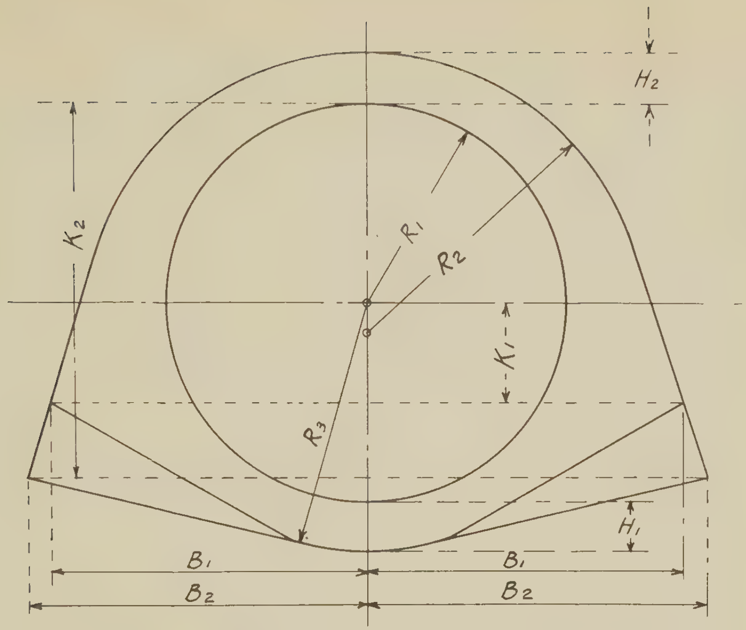

FIG. 12.—LOUISVILLE STANDARD CONCRETE SECTION.
Courtesy of McGraw-Hill Book Co.

DIMENSIONS OF THE SECTIONS
(Fig. 12)

Diameter	H1	H2	B1	B2	K1	K2	R1	R2	R3	Quantity of Concrete, cu. yd. per lin. ft. sewer	
										Firm Ground	Soft Ground
24″	5″	5″	1′ 7¼″	1′ 8¼″	6″	1′ 10½″	1′ 0″	1′ 6″	1′ 5″	0.13	0.15
27″	5″	5″	1′ 9⅝″	1′ 10¾″	6¾″	2′ 1 5/16″	1′ 1½″	1′ 8″	1′ 6½″	0.15	0.18
30″	5″	5″	2′ 0″	2′ 1½″	7½″	2′ 4⅛″	1′ 3″	1′ 10″	1′ 8″	0.18	0.21
33″	5″	5″	2′ 2⅜″	2′ 4¼″	8¼″	2′ 6 15/16″	1′ 4½″	2′ 0″	1′ 9½″	0.19	0.23
36″	5″	5″	2′ 4¾″	2′ 6¾″	9″	2′ 9¾″	1′ 6″	2′ 2″	1′ 11″	0.22	0.26
39″	5″	5″	2′ 7¼″	2′ 9¾″	9¾″	2′ 0 9/16″	1′ 7½″	2′ 4″	2′ 0½″	0.25	0.29
42″	6″	6″	2′ 9⅝″	3′ 0″	10½″	3′ 3⅜″	1′ 9″	2′ 6″	2′ 3″	0.29	0.35
45″	6″	6″	3′ 0″	3′ 2½″	11¼″	3′ 6 3/16″	1′ 10½″	2′ 8″	2′ 4½″	0.33	0.40
48″	6″	6″	3′ 2⅜″	3′ 5¼″	1′ 0″	3′ 9″	2′ 0″	2′ 10″	2′ 6″	0.38	0.45
51″	6″	6″	3′ 4¾″	3′ 8″	1′ 0¾″	3′ 11 13/16″	2′ 1½″	3′ 0″	2′ 7½″	0.41	0.49
54″	6″	6″	3′ 7¼″	3′ 10¾″	1′ 1½″	4′ 2⅝″	2′ 3″	3′ 2″	2′ 9″	0.43	0.53
37″	6″	6″	3′ 9⅝″	4′ 1½″	1′ 2¼″	4′ 5 7/16″	2′ 4½″	3′ 4″	2′ 10½″	0.47	0.57
60″	6″	7″	4′ 0″	4′ 4″	1′ 3″	4′ 8¼″	2′ 6″	3′ 6″	3′ 0″	0.53	0.65
63″	6″	7″	4′ 2⅜″	4′ 6½″	1′ 3¾″	4′ 11 1/16″	2′ 7½″	3′ 8½″	3′ 1½″	0.57	0.71
66″	6″	7″	4′ 4¾″	4′ 9¼″	1′ 4½″	5′ 1⅞″	2′ 9″	3′ 10″	3′ 3″	0.61	0.77
69″	6″	8″	4′ 7¼″	5′ 0″	1′ 5¼″	5′ 4 1/16″	2′ 10½″	4′ 0″	3′ 4½″	0.66	0.84
72″	6″	8″	4′ 9⅝″	5′ 2¾″	1′ 6″	5′ 7½″	3′ 0″	4′ 2″	3′ 6″	0.70	0.88

Plain vs. Reinforced Construction. The structural properties of concrete are such that for a structure subjected to possible bending, as a sewer may normally be, the basic condition on the elastic arch theory leads to a reinforced shell. Where direct compression combines with the bending moments in a way to eliminate tensile stresses, a condition of zero reinforcement occurs. It is probably true that many extreme designs of concrete and of brick sewers are standing after incipient failure, because of the passive resistance of the earth at the haunches. This makes necessary a close scrutiny of the character of the soil, whether hard or soft, in working up a design.

In hard material with sufficient cover, the shape of the sewer arch can often be arranged to conform to the load line found by analysis. This may save reinforcing.

Rectangular sewers will always require reinforcing in the top beam, unless this is so thick that arch action occurs, which may not be economical. The sides and bottom will usually need reinforcing also, particularly in the softer materials.

As a general rule in the smaller sizes from three up to eight ft. in diameter contractors prefer to build monolithic concrete sewers, without reinforcement. This makes for simplicity and speed in construction, as the concrete usually can be deposited more quickly than the steel can be placed. Plain monolithic concrete is most suitable in trenches of moderate depth, in firm soils, with light live loads, in locations where no restrictions are placed on head room. While monolithic sewers have been built in firm soils up to 17-ft. in diameter, without reinforcement, bottom conditions or special loadings may dictate a small amount of steel as insurance. Certainly in large sewers from ten ft. up steel reinforcement is often desirable and generally used. The cross-section of concrete is thereby reduced. Structurally reinforced concrete sewers are applicable to all conditions of soil and loading. An analysis of cost under these particular conditions may show the best course to pursue. In the design sometimes cases occur where the invert alone may need reinforcement and again where the arch alone may need it.

In the field the use of reinforcing steel to meet unexpected soil conditions may make local use in any sewer worth while. In soft soils the sewer must act as an elastic ring rather than an arch, in order to distribute the load over the foundation. This condition will usually require some reinforcement except in the very small sizes.

Reinforcing Steel. The reinforcement is generally a steel bar of some kind, plain, twisted, or deformed. Round and square bars are in use. The quality of the steel used is covered by excellent general specification, of the American Society of Testing Materials, as well as by the standard Sewer specification of this Society. Many designers prefer a high carbon steel with high elastic limit, others a medium steel. All usually prefer new material, of open hearth manufacture. Ability to bend readily is a usual test. Brittle steel is not desirable.

In sewer construction of any size, bar reinforcement is used rather than mesh. Except in very small sewers, the mesh does not supply enough steel to meet the needs of the designer. This is also because of the amount of steel required in one direction across the arch. Only sufficient longitudinal steel is required for spacing and shrinkage or temperature stresses during construction. The amount of longitudinal steel varies with the designer and the condition in some offices as low as 0.1 of 1 per cent of the cross-section has been used. For tight work free from cracks as high as 0.4 of 1 per cent is used.

The handling, storage, and placing of steel are matters generally put up to the contractor. However, the steel should be handled to prevent unnecessary bending and stored to prevent useless rust, which may later need to be cleared away. In the placing, various methods have been used. The steel may be secured to the forms by steel chairs, or wired to the spacers which separate the forms. Occasionally bricks or blocks of wood are used. These are likely to be displaced and necessitate watching. The use of chairs or spacers of steel to be left in should be encouraged.

In the larger work, bending of the steel at the mill or shops is very common. In the smaller sizes, bending on the job is frequent.

Stock piles conveniently located and plainly marked are very serviceable.

Influence of Soil Conditions. Soil conditions are one of the most important points in the design of a sewer. While soil conditions may be learned approximately by borings and preliminary exploration, the true soil condition is often not learned until every foot is opened up. While soil conditions materially influence the design of the invert in most types of sewers, they have a most important bearing on all arch design, unless the arch is made self-contained as was done in the early days in brick sewer design. Consequently a knowledge of soil conditions is all-important.

In hard stiff soils, like blue clay, where complete and stiff backing can be obtained with concrete, a thinner section can be used than in loose running soils or compressible material. In all soils care should be taken to have the backfill thoroughly compacted on the haunches, unless the sewer is so designed as to minimize the value of this precaution.

In rock a sewer invert may be called upon to take but little stress. In stiff soils, the invert will distribute readily the load from the sides without making heavy stresses. But in compressible soils, the invert may require special design and reinforcing to distribute evenly, the weight of the sides and the bending movements on the soil material without cracking. For this purpose and in emergencies, reinforcing steel is very useful.

In very soft foundations, where thickening of the invert or reinforcing with steel will not suffice, plank foundations, alone, or plank on piling may be required. The extent and amount of timbering or piling depends on the local conditions and should be governed by ripe experience. Plank foundations are often made with 3-in. plank laid on the trench bottom, in two layers crossed. Where piling is required to bridge sand pockets, mud or

similar material the piles are driven first. On the pile bents waling stays may be spiked, on which are laid longitudinally plans to sustain the concrete until thoroughly hardened.

The judging of existing and future soil conditions is one of the hardest problems of sewer design and requires experience with similar soil and judgment to determine what loading can be expected on the sewer. In very soft soil, conditions during construction may call for foundation piling or planking that will not be required after the sewer is completed and the trench backfilled, as the completed sewer fill of water will not differ by a large percentage from the weight of the soil displaced. The sewer empty may even show a figured tendency to rise or float. This leaves the foundations under the sewer with the sole use of preventing unequal settlement. With longitudinal reinforcement the sewer, especially the side walls become continuous girders that will bridge over small soft spots.

Invert Lining. Sewer inverts are usually built of concrete in concrete sewers. In the past, where excessive velocities have been expected, lining with tile or brick has been adopted. Except in extreme cases, this is not resorted to in present practice, so much as in the past. Where steep grades and grit are encountered this protective phase should be investigated. Lining means additional cost, because the use of a material of this type as a lining may slow up construction. Rich dense concrete floated to a hard finish should be good for velocities up to 15 or even 20 ft. per second. In a sewer such velocities are usually only very occasional.

The resistance of concrete or other materials to scouring action is a subject on which little data is available. Tests made by E. S. Rankin and described in the proceedings of the American Society of Municipal Improvements indicate that good concrete wears surprisingly well, and that under continued wear of heavy abrasion in his tests six in. of good concrete should be equivalent under the same conditions to a high grade paving brick four in. in thickness.

In placing concrete on inverts, the method of construction must be carefully worked out to secure the best hydraulic results, i. e., a smooth invert on uniform grade. A liberal use of pieces of reinforcing steel driven in to correct grade is helpful. In some shapes of sewer the use of precast concrete blocks to carry the forms has proved worth while. In other shapes, the placing of a segment of the bottom in a section has been successfully screeded to a hard finish. In large sections with comparatively flat bottoms the bottom should be placed first and preferably screeded to finish. Plastering afterwards on a rough bottom is difficult.

Placing Concrete. The consistency should be plastic enough to flow readily in the forms and around reinforcing steel. According to modern investigations, too wet a mix is as bad as too dry. The sidewalls and lower portion of the arch can be put in with a wetter mix than the crown.

By judicious use of outside forms and choice of consistency a dense arch can be secured. Where trenches are wet, the mix for the bottom is often made rather dry to absorb moisture in the trench. Where the invert is reinforced a lean mix may be placed as a skin coat in moist trenches.

The placing of concrete is usually done from the bank. Spouts or troughs permit ready placing inside the forms.

Mixing. The mixing is usually done by a portable plant on sewer work of the smaller sizes. On large work where 20 to 40 ft. make a good daily run, a central mixing plant may be worth while of a semi-portable type. This plant can be arranged to move, from time to time, to save long travel of the mixed concrete in the cars.

On large work the materials can well be brought up on standard gage cars where space permits. On small jobs, team delivery or narrow gage haul from rail connection are usual.

Cement nowadays is frequently tested before leaving the mill, so that sufficient time elapses for the 7 day test to mature before the cement goes into the work. Hence the contractor generally carries only enough cement on hand to tide over any delay on transportation.

Forms. On standard sections, steel forms have grown in use during the last ten years, on sewer work. The type of form must be selected for the work. A different type being used frequently in tunnel work from that in open cut. Ease of handling and sufficient stiffness and weight to stand use are requisites of successful forms. Steel forms must be kept clean and oiled.

On special work or short jobs, wooden forms are often resorted to, because of the ready applicability to meet all conditions and the speed of construction.

Where reinforcing steel is to be placed, special attention should be given to the form design to provide means of holding the steel accurately in place.

Removal of Forms. The hardening of the concrete before removal of forms varies considerably with the weather and size of the sewer. In warm weather removal is possible in 24 to 36 hours on the smaller sizes and 48 hours and up on the larger. In cold weather longer periods are desirable. Backfilling usually can commence in from 3 to 7 days. Care should be taken to avoid eccentric loading and shock from dumping.

Cold Weather. Cold weather precautions may be varied. The water or aggregates may be heated. The work when in place may be heated by salamanders or by steam pipes. Tarpaulins may be used to cover the trench. Every necessary precaution must be used to prevent the freezing of the concrete before hardening. The best practice seems to be to avoid the use of any soluble chemicals which will reduce the freezing point of the water. Many specifications for sewers limit the winter work. Others

forbid all work in open cut between certain dates, covering the winter months. This is a matter of regional practice.

Concrete hardens more slowly in cold weather, so that in cold weather too early removal of forms must be carefully guarded against.

Aggregate. The choice of aggregate rests somewhat on local markets. In general well graded materials are sought. In many localities natural sands or gravels are better graded than artificially crushed stone. Good work can usually be done, however, with suitable combinations. As a rule the use of rock screenings instead of sand is barred.

The proportions of sewer concrete mix vary somewhat between limits of 1 cement to 5 of fine and coarse aggregates and 1 of cement to 9 of fine and coarse aggregates. A very common mix, particularly for reinforced work is 1 to 6, i. e., 1 : 2 : 4. In many localities with commercial aggregates, 1 to 9, i. e., 1 : 3 : 6 appears too lean for good work. Many designers feel that the difference between the cost of a 1 : 2 : 4 and a 1 : 2½ : 4½ mix or a 1 : 3 : 5 is so little compared to the other costs, that the richer mix is preferable throughout.

LIST OF REFERENCE BOOKS ON THE DESIGN AND CONSTRUCTION OF MONOLITHIC CONCRETE SEWERS.

Sewerage and Sewage Treatment, H. E. Babbitt
John Wiley and Sons, New York, 1922
(432 Fourth Avenue) $5.00

Sewage Disposal, G. W. Fuller
McGraw-Hill Co., 1912
(370 Seventh Avenue, New York, N. Y.) 7.00

Sewerage and Sewage Disposal, Leonard Metcalf and H. P. Eddy
McGraw-Hill Co., 1922 .... 5.00

American Sewerage Practice, Leonard Metcalf and H. P. Eddy
Vol. 1 Design of Sewers $6.00
Vol. 2 Construction of Sewers 5.00
Vol. 3 Disposal of Sewage 7.00

Sewer Construction, H. N. Ogden
John Wiley and Sons, 1911 .... 3.00

Concrete Engineer's Handbook, G. A. Hool and N. C. Johnson
McGraw-Hill Co., 1918 .... 6.00

Reinforced Concrete Construction, G. A. Hool
Vol. 1 Fundamental Principles $2.50
Vol. 2 Retaining Walls and Buildings 6.00
Vol. 3 Bridges and Culverts 6.00
McGraw-Hill Co., 1913

A Treatise on Concrete, Plain and Reinforced, Third Edition
F. W. Taylor and S. E. Thompson
John Wiley and Sons, 1917 .... 5.00

Principles of Reinforced Concrete Construction, Third Edition
F. E. Turneaure and F. R. Maurer
Wiley and Sons, 1919 .... 3.75

Sewerage; the Designing, Construction and Maintaining of
Sewerage Systems and Sewerage Treatment Plants
A. P. Folwell
John Wiley and Sons, 1918 .... 6.00

REPORT OF COMMITTEE C-3, ON TREATMENT OF CONCRETE SURFACES.

Including revision of Standard No. 25, "Recommended Practice for Portland Cement Stucco," and new tentative standard, "Recommended Practice for Treatment of Exterior Surfaces of Industrial Reinforced-Concrete Buildings."

The efforts of the committee during the past year have been confined to the preparation and submission for adoption of two standards conforming to the requirements as set forth last year by Committee G-3.

One of these is a revision of the existing Standard No. 25, "Recommended Practice for Portland Cement Stucco," including a revision of form and embodying the changes that have been recommended and approved by the committee since 1920.

The other is a new standard, "Recommended Practice for Treatment of Exterior Surfaces of Industrial Reinforced Concrete Buildings."

This standard embodies the material pertaining to this subject in the committee's report for 1921, together with numerous additions and revisions. It has received the approval of the committee except for a single reservation in regard to the questionable success of using a plain grout of cement and water, or of cement, sand and water, as specified in the practice.

It is believed that more definite information on this, as well as on other items in the practice as submitted, will probably be obtained within the next year or two, and that unless there are more important reasons for introducing changes in the proposed standard, it should be adopted for the sake of the generally authentic information it contains, and for the very useful purpose it will serve.

J. G. AHLERS,
W. J. BALLINGER,
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J. E. FREEMAN,
ARTHUR J. GARROD,
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C. N. GODFREY,
GEORGE E. HORR,
M. A. ILLING,
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F. A. HITCHCOCK, *Secretary*.

DISCUSSION.

A. B. Cohen *(by letter)*.—On p. 292, Vol. 18, *Proceedings*, American Concrete Institute, in the course of a brief discussion of bituminous bond coats, the writer mentioned the successful use of material in this general class on the underside of a reinforced-concrete flat slab viaduct at South Orange, N. J. The underside of this slab formed the ceiling for the D. L. & W. R. R. station upon which a coat of plaster was applied. The slab is 1 ft. 8 in. in thickness and is supported on columns forming a panel 18 ft. 9 in. x 20 ft. The slab carries a large volume of suburban passenger trains, the track being laid in 1 ft. of rock ballast. This structure has been in service six years and the plaster has remained intact and in good condition. Mr. Cohen.

It is desirable to explain in justice to everyone concerned that this successful job of plaster bond was not accomplished with bituminous bond coat by the methods ordinarily applied and are understood in connection with such materials. The concrete slab before the application of the plaster was treated by the Par-lock patented process of the Vortex Manufacturing Co. which employs special equipment first in the application of the bituminous coat and later embodying in that coat a course rock grit. It was by these special methods on this particular work that a successful job was attained.

I might add that the conditions were quite severe. The underside of the slab is not housed for station purposes, is covered by a great deal of moisture and condensation during certain atmospheric conditions, the structure being located in a low point of the valley.

Tyrell B. Shertzer.—I wish to register my objection to requirements in the report of Committee C-3, Standard Recommended Practice for Portland Cement Stucco, Section III, Paragraphs 11, 12 and 14. I note in these paragraphs that it is required that tile, brick and concrete block should be set in cement mortar; that in the requirements for mortar for tile, one-fifth part hydrated lime may be added. There is ample evidence, as shown by the data presented on pp. 54 to 61 inclusive, National Lime Association Bulletin No. 306, that mortar composed of one part portland cement, one part lime, and six parts sand results in stronger masonry than when straight cement mortar is used. Mr. Shertzer.

It strikes me that the restrictions placed on mortar in the abovementioned paragraphs are unfair and needlessly expensive.

TENTATIVE STANDARD RECOMMENDED PRACTICE FOR TREATMENT OF EXTERIOR SURFACES OF INDUSTRIAL REINFORCED CONCRETE BUILDINGS.*

I.

SCOPE AND GENERAL REQUIREMENTS.

Scope

1. This Recommended Practice is designed to outline approved methods of treating the surfaces of concrete factories, warehouses, and other industrial buildings, in such manner as to produce pleasing and durable surfaces at costs which are not inconsistent with the occupancy and surroundings of such buildings.

General Requirements

2. Good exterior appearance of concrete buildings depends fundamentally on care in the building of forms for the outside beams and columns. Boards used in column forms should always run vertically, and in beams horizontally, and should preferably be of even width in order that the board marks be continuous throughout the length of the column or beam. Sound, clean lumber of sufficient strength should be used, and the forms properly braced in order to preserve the straightness and trueness of the general lines. The concrete should be carefully proportioned, mixed, and placed in order to reduce to a minimum the need for pointing, patching and other corrective treatments.

> *Note:*—Industrial buildings, as a rule, are located in districts where appearance is a matter of secondary importance. The cost of any surface treatment, is therefore, of prime importance, and circumstances are usually the governing factor in the selection of the type of finish. It is a fact, however, that a reasonable expenditure is justified in making the exterior of a building attractive to the public as an advertising feature, if for no other reason. Under any consideration all concrete structures should at least have all voids pointed, and exposed wires, nails and bolts removed or cut off so as to guard against disintegration from the action of the elements. From this required minimum one may go to the costly extremes of inlaid tiles or brick and stone veneers, but such treatments are to be considered from the architectural view point, and are beyond the scope of this practice, which is limited to the treatment of the concrete itself as it comes from the forms. Due to the very nature of concrete, the forms are subject to a certain amount of movement while being filled, no matter how careful the supervision or workmanship. No amount of work will correct the faulty appearance of a building unless the general lines are good, and it is, therefore, essential to guard in so far as possible against bulging and distortion of forms. It is also obvious that care in concreting will eliminate unnecessary expense in finishing, and at the same time give better results. A reasonable amount of precaution to prevent the occurrence of conspicuous defects is better than the cure of such defects afterwards.

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*Accepted as Tentative Standard by the Annual Meeting of the Institute, Jan. 22-25, 1923.

II.

CLASSIFICATION OF SURFACE TREATMENTS.

Classes of Treatments

3. The surface treatments described herein are divided into the following five general classes:

a. Pointing and Patching (minimum requirements).

b. Correction of Column and Beam Lines, Fill Joints, etc.

c. Cement Washes and Proprietary Paints.

d. Rubbed Finishes.

e. Tooled Finishes.

The recommended methods for producing these finishes are given in detail in the following sections:

A. Pointing and Patching (Minimum Requirements).

Painting and Patching

4. All nails, wires, and bolts should first be removed or cut back to a depth of at least one in. from the surface of the concrete, to provide sufficient key for the pointing mortar, and to insure against water reaching any pieces of iron or steel and causing rust spots or spalling.

5. Bolt holes should be filled with corks of ⅛ in. greater diameter than the holes. The corks should be driven into the holes until the head is one in. back from the surface.

6. Before pointing, all defective places should be thoroughly cleaned of dust, loose pieces, laitance and foreign particles (such as saw dust). The spot to be patched and the concrete immediately around it should then be saturated with water. A mortar of one part cement and two parts of clean building sand should then be forced into all parts of the cavity or defective spot, and the surface rubbed with a cork or wood float. Any mortar that may work out and lap over on the sound concrete should be removed with a clean dry brush or a piece of bagging.

7. If large patches of considerable depth and area occur, the mortar should be applied in two or more coats. Each undercoat should be scored as in plaster work, but it is not necessary or desirable for each coat to become entirely dry before applying the next.

8. Patching should be avoided in hot sunshine or quick drying wind, unless it is feasible to protect the fresh mortar with wet burlap or canvas.

> *Note:*—The pointing and patching treatment outlined above naturally leaves a somewhat spotty appearance, but after weathering for several months the entire surface will begin to assume a fairly uniform color. A pointed place will usually show up as a dark spot on the body of the building unless the mortar used is somewhat lighter in color than the mortar used in the concrete. This can be corrected by using a little white cement or a light colored sand in the pointing mortar. It has become quite common practice to use white beach sand, but the Committee would recommend a bank or dredged sand which has been screened through a No. 10 sieve. Final rubbing of patches should be parallel to board marks of surrounding area so as to make patch as inconspicuous as possible.
>
> It is to be noted that the treatment prescribed in this section is that which is warranted entirely from the standpoint of utility, rather than from that of appearance.

B. Correction of Column and Beam Lines, Fill Joints, Etc.

Correction of Lines

9. This section is supplementary to Section A and prescribes additional corrective treatment, but not to the extent of eliminating board marks or bringing the surface to uniform color.

10. The building should first receive the pointing and patching treatment where required, as described in paragraphs 4 to 8 inclusive.

11. Workmen should be instructed to watch for steel reinforcement near the surface, and if this condition should be found special precautions should be taken to protect such steel from rust.

> *Note:*—When reinforcing steel in exterior members is not back at least one full in. from the outside face of the concrete, moisture works its way in causing it to rust. Eventually this rusting if continued will spall off the concrete and cause an unsightly appearance and may even in severe cases affect the strength of the structure. Good design should never call for such sizes of hoops, spirals, stirrups, etc., as will necessitate steel within one in. of the surface, but sometimes due to careless placing the steel will be at or near the surface.
>
> To correct this condition cut out the concrete around the steel on all sides and if the bar is of minor importance cut it off well back from the surface. When it is not advisable to cut out the steel the recess should be cut large enough so as to bend the steel back from the surface.
>
> If important and large bars should be encountered where it is not desirable or feasible to either bend back or cut off the steel the bar should be painted with red lead and then wrapped loosely with No. 16 iron wire to insure a bond and the recess carefully pointed.

12. Beams with sag or bulge, and columns which are out of plumb should be cut to line.

13. Nail head marks, fins and other small projections should be removed.

> *Note:*—It has been found that pounding with a flat headed hammer will cause the projection to crumble down to the general level of the surrounding surface. This method gives better, quicker and cheaper results than cutting with a chisel, which may have to be used on projections of considerable size.

14. Fill lines should be dressed by thoroughly cleaning the joint and then applying mortar and finishing with cork or wood float, as described in paragraph 6.

> *Note:*—Good judgment must be used in deciding how far the more expensive work of truing up bad lines should be carried, as considerable money may easily be spent without materially improving the general appearance.
>
> When cleaning up and pointing around windows and miscellaneous iron particular care should be taken to cut clean sharp edges, and not allow a film of mortar to lap over the steel, for this film will in time break away and leave a ragged edge, and may, in the case of windows, cause a leak.
>
> If a prominent board mark has been erased by the pointing, the patch will not be so noticeable in contrast to the body of the building if the mark is ruled in again.
>
> It is estimated that the treatment prescribed in sections A and B will require about one and one-half bags of cement per 1000 sq.

ft. of surface. The cost will average between 2 and 3 cents per sq. ft. with cement masons at 75c per hour and labor at 40c per hour. The actual cost in specific cases may vary considerably from this estimate, according to the quality of the form work and the concreting.

C. Cement Washes and Proprietary Paints.

(a) Cement Washes.

15. Cement washes of practically any color from white or cream to cement gray can be prepared by varying the proportions used of white or gray cement and light or dark sand. A mixture of 1 part white cement and 1 part finely screened yellow bank sand, with 5 per cent of hydrated lime (by volume of cement) will give a serviceable color just off the white, and will serve as an example of a typical dry mixture. **Cement Washes**

16. After the cement, sand and lime in the desired proportions are thoroughly mixed in the dry state, the mixture should be added slowly to water, stirring vigorously until the consistency is that of a stiff oil paint. The dry batch should be large enough for a full day's work, but only enough of the wash should be prepared to last one hour. The wash should be fully stirred in the container before each application to the concrete surface, and when refilling the container all the old wash should be cleaned out and discarded. **Mixing**

17. Before applying the wash, all pointing and patching should be completed as indicated in Sections A and B. The area to be coated should first be thoroughly wet, and then a full brush coat of the wash applied. This coat should be rubbed in with a cork float, the surface being sprinkled with a little additional water if necessary. Finally the surface should be gone over with a clean damp brush, brushing in the direction of the board marks. In this process all excess material should be removed, and the remaining coat should be as thin as will permit the surface to be entirely covered. **Application**

18. In coating adjacent areas the brush marks should be carefully blended to avoid a line between the two areas. The work should be so planned that joinings occur at natural breaks in the surface. **Joinings**

19. In warm or drying weather the finished surface should be sprinkled with water once a day for three days, and in cool, damp weather should be sprinkled at least once within 24 hours after finishing. **Wetting**

Note:—The sand must be dry before screening not only to facilitate the screening but also to avoid the possibility of moisture in the sand causing a set in the dry mix. Best results seem to be obtained with a No. 18 sieve.

Whenever a cement wash is to be used, less attention need be given to the color and finish of patches as described in the note under Section A, since it is apparent that the applied coating will give the desired uniformity to the concrete surface. This coating should, however, be as thin as possible, for a thick coat will eventually craze and peel off.

A very fine appearance is obtained if the wash is rubbed in with a carborundum stone. This not only insures a better bond, by more positively forcing the material into the pores of the concrete, but at the same time grinds down any slight projection, leaving a semi-rubbed surface.

Sprinkling of the freshly coated surface is necessary, for if the wash dries before it has attained its set, it will dust off. A very practical way to sprinkle the surface is to make up two perforated pieces of pipe about four feet long, on a "T" and plug the ends. Then connect a hose to the leg of the "T" and lower the pipe down from the roof over the face of the columns and walls. Spray nozzles can also be used to advantage. The sprinkling must be gentle so as not to wash off the fresh coating.

The Committee has been informed that a very effective way of insuring the bond of the wash coat is to use a 4 per cent solution of commercial calcium chloride as the gaging liquid instead of plain water. This solution is made up by dissolving one lb. of the chloride in three gallons of water. The calcium chloride attracts moisture from the air and keeps the wash coat damp for several days, thus insuring that the cement sets before it dries out.

The cement wash will cost about 2 cents per sq. ft., and will require about one bag of cement per 1000 sq. ft. Adding the cost of the work specified under Sections A and B the total cost of this methhod of surface treatment would be about 5 cents per sq. ft. with cement masons at 75c per hour, and labor at 40c per hour, and the total material one and one-half bags of gray cement and one bag of white cement per 1000 sq. ft.

(b) Cement Paints.

Proprietary Coatings

20. Whenever proprietary cement paints or coatings are to be used, the manufacturer's directions should be followed in their application.

Note:—The Committe recognizes that there are many paints and coatings for concrete on the market which have been widely used, and have given satisfaction. It cannot, however, give its endorsement to particular proprietary materials, owing to its own limited facilities for conducting the exposure tests and field inspections on which ratings should be based.

D. Rubbed Finishes.

Rubbed Finishes

21. The rubbed finishes are obtained with carborundum stones. The first rub should be completed as soon as the forms can be removed. Faces and sides of columns should be stripped in 24 hours, if possible, and the soffits of beams should be treated within three or four days.

First Rub

22. As soon as the forms are removed the surface should be thoroughly wetted and then rubbed with a No. 20 carborundum stone. The rubbing will remove fins, board marks, nailhead marks, and to a certain extent the irregularities between boards.

23. The cement paste which works up in the rubbing process should be removed by washing and brushing. Small voids in the concrete should be filled with a mortar (usually 1:2) composed of finely screened aggregate of the same general description as that used in the concrete. This mortar should be worked into the face with the carborundum stone and left even and regular.

Note:—The best and most economical results are obtained by applying the first rub to the concrete while it is "green." Filling of the small voids with mortar as described in paragraph 23 offers no difficulties, but the operator should be warned against leaving an appreciable thickness of mortar on the face of the concrete to take up irregularities in the surface, unless special precautions are

taken to insure the bond. Such precautions are particularly necessary when the surfacing is delayed until the concrete has hardened and dried out.

24. If the concrete cannot be given the first rub when it is still "green," board marks, nailhead marks, and small projections must first be removed as indicated in paragraph 13. After thorōugh wetting, the surface should receive the cement wash application as described in the first part of paragraph 17, in order to help the grinding action. (See also the second paragraph in the note following paragraph 19). The carborundum rub should then be given as prescribed above, being sure to remove all the cement wash by washing and brushing. **Second Rub**

25. The second rub should be applied near the end of the work, when the building is ready to clean down and danger of staining from other work is past. The surface should be thoroughly wet and then gone over with a No. 24 carborundum stone. The paste which is worked up should be removed with a wet brush or clean bagging. When dry the finished surface will resemble limestone in color and texture.

Note:—When using the rubbing method described in this section it is essential that *all* patching, correction of lines, etc., be done before or during the first rub. When the second rub is performed nothing but the stone and plenty of water should be used. The irregularities of color or texture which are noticeable after the first rub need not be considered as the second rub brings the surface to an almost uniform color.

The cost of this process including miscellaneous pointing and first and second rub should cost about six cents per sq. ft. with masons at 75c per hour and labor at 40c per hour.

E. Tooled Finishes.

26. As here used, tooled finishes include all finishes in which the surface of the concrete is mechanically roughened, or removed to expose the aggregate. Wire brushes, stone dressing tools, and rotary cutters are used for this purpose. **Tooled Finishes**

27. When coarse aggregate is to be exposed by wire brushing, the concrete should be as green as possible, usually not over 48 hours old. Generally speaking, this process is not practicable on large buildings, unless special effects are to be obtained, in which case the treatment, if it is to be successful, requires careful preparation and selection of aggregates, as well as extreme care in concreting. **Wire Brushing**

28. When bush hammering, crandalling or other tooling treatment is to be used, considerable thought should be given to the proper layout of construction joints and fill lines, and plans showing the treated areas should be issued before any concrete is placed. The work should be planned to eliminate as many joints as possible, particularly horizontal fill lines. If the latter are unavoidable they should be absolutely level. **Bush Hammering, Crandalling, etc.**

29. Where coarse aggregate is to be exposed by picking or hammering, it should be of uniform size or uniformly graded. The distribution of the aggregate should also be uniform for satisfactory results, and the consistency of the mix should, therefore, be carefully controlled in order to prevent the settling or segregation of aggregate. **Picking or Hammering**

Patching 30. When patching or filling of bolt holes is required on an area which is to receive a tooled finish, the tooling should precede the patching. The latter should then be done by a skilled workman who should match the texture of the surrounding area by imbedding selected pieces of large aggregate in a mortar bed.

Rough Textures 31. Surfaces to be finished with a rough texture, shoild be at least two weeks old before finishing. The work may be executed by mechanical devices operated by air or electricity, or by hand hammering. In general the work on any one panel or area should be done by the same operator in order to avoid differences in texture.

Paneling 32. As the tooled finishes are usually carried out in panel effects, great care should be taken to lay out exact lines and to cut clean and sharp at the edges. The borders of the panels and such other parts of the surface as are not roughened must receive the usual pointing as described in Sections A and B, and also one of the wash or rubbed finishes, to balance with the tooled areas.

Note:—In the Committee's opinion the effects that are possible under the various tooling treatments are the most pleasing of any, but at the same time are the most costly and difficult to do. They must also be considered entirely from an aesthetic view point as they do not add to the weather resisting qualities of the concrete, and in fact tend to its disintegration, if the concrete is not of the best.

The success of tooling depends upon uniformity in the results obtained, and, therefore, special attention is called to the importance of avoiding joints, fill lines, laitance and segregation. Careful selection of aggregate helps in attaining the desired uniformity, and if the aggregate be selected for color, its exposure by tooling will introduce effects in color variation, as well as in texture.

STANDARD RECOMMENDED PRACTICE FOR PORTLAND CEMENT STUCCO.*

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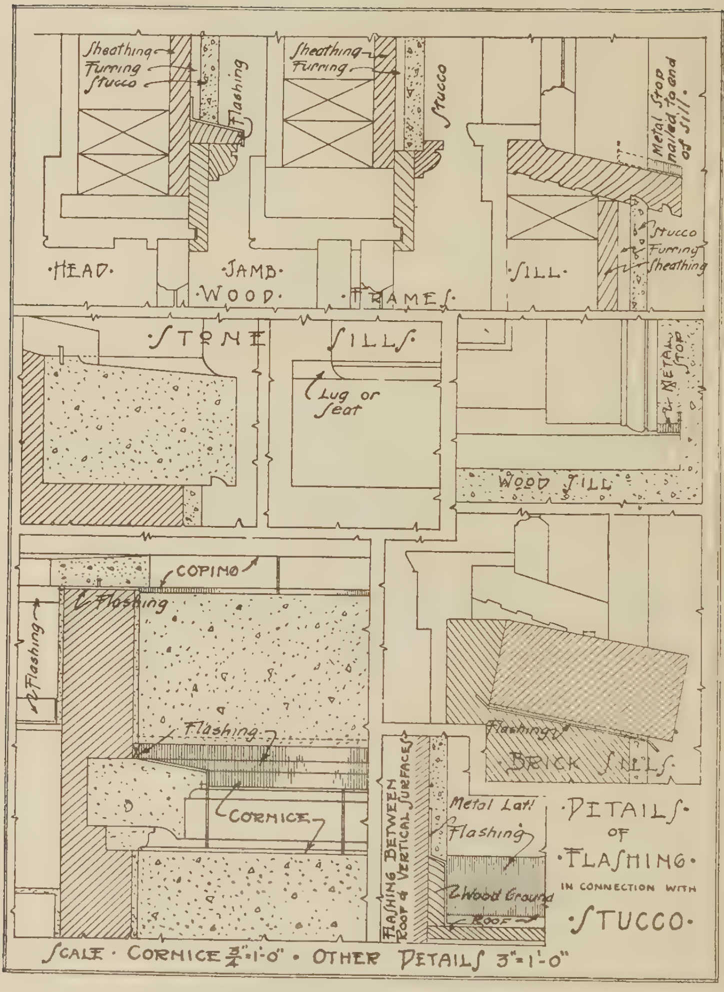
*Revision of Standard No. 25, "Proceedings," A. C. I., v. 16, 1920, p. 304; Adopted by Letter Ballot of the Institute, Apr. 1, 1923.



ARCHITECTURAL DETAILS STUCCO APPLICATION

I. GENERAL.

1. *Design.*—Whenever the design of the structure permits, an overhanging roof or similar projection is recommended to afford protection to the stucco. Stuccoed copings, cornices and other exposed horizontal surfaces should be avoided whenever possible. All exposed stuccoed surfaces should shed water quickly, and whenever departure from the vertical is necessary, as at water tables, belt courses, and the like, the greatest possible slope should be detailed. Stucco should not be run to the ground whenever other treatment is possible. Should the design of the structure require this treatment, the backing should be of tile, brick, stone, or concrete, providing good machanical bond for the stucco, and should be thoroughly cleaned before plastering. Unless special care is taken to thoroughly clean the base and each plaster coat from dirt and splash before the succeeding coat is applied, failure of the stucco may be expected. Design

> *Note.*—Successful stucco work depends in large measure upon suitable design of the structure for stucco. Exterior plaster of any kind merits whatever protection can legitimately be given it, and while concession must sometimes be made to architectural requirements, there is rarely any necessity for subjecting stucco to an exposure which it cannot reasonably be expected to withstand.

2. *Flashing.*—Suitable flashing should be provided over all door and window openings wherever projecting wood trim occurs. Wall copings, cornices, rails, chimney caps, etc., should be built of concrete, stone, terra cotta, or metal with ample overhanging drip groove or lip, and water-tight joints. If copings are set in blocks with mortar joints, continuous flashing should extend across the wall below the coping and project beyond and form an inconspicuous lip over the upper edge of the stucco. Continuous flashing with similar projecting lip should be provided under brick sills. This flashing should be so installed as to insure absolute protection against interior leakage. Cornices set with mortar joints should be provided with flashing over the top. Sills should project well from the face of the stucco and be provided with drip grooves or flashing as described above for brick sills. Sills should also be provided with stools or jamb seats to insure wash of water over the face and not over the ends. Special attention should be given to the design of gutters and down spouts at returns of porch roofs where overflow will result in discoloration and cracking. The end joints should be thoroughly protected with sheet lead flashings. A 2-in. strip should be provided at the intersection of walls and sloping roofs and flashing extended up and over it, the stucco being brought down to the top of the strip. Double flashing should be used at the intersection of sloping roof with metal lath wall. The metal lath should be stapled into the upper or cap flashing at its upper edge which is rigidly attached to the wall behind. Flashing

> *Note.*—Even where stucco will remain structurally sound, it is sometimes wiser to use other treatment for the sake of appearance. For example, it is better not to run stucco to grade,

not only because of the danger from frost action, but also to avoid staining of the stucco from dirt and moisture. For the same reason special attention should be given to details of flashing and drips, wherein a little foresight, will prevent much unsightly discoloration, and possibly more serious defects.

Where horizontal word trimming courses occur in stuccoed walls satisfactory results have been secured by making these wood courses of stock approximately 2 in. thick, rabbetted on top with the stucco extending down over the inside lip, thus doing away with flashing. Where flashings are used on furred walls, it is important that they extend back of the furring strips.

A fundamental rule in the design of a stucco structure is "Keep water from getting behind the stucco." The architect should go even further than this and endeavor to keep any concentration of water flow from getting at the stucco at all. Real study of methods of avoiding leaks and drips and of providing properly for roof drainage will be well repaid.

Preparation of Original Surface

3. *Preparation of Original Surface.*—(a) All roof gutters should be fixed, and downspout hangers and all other fixed supports should be put in place before the plastering is done, in order to avoid breaks in the stucco.

(b) Metal lath and wood lath should be stopped not less than 6 in. above grade to be free from ground moisture.

(c) All trim should be placed in such manner that it will show its proper projection in relation to the finished stucco surface, particularly in overcoating.

Note.—Paragraphs 1 to 3 contain definite suggestions for stucco protection. These are supplemented herewith by the simple drawings which show typical details for such protection. (See drawing of details.)

II. MATERIALS.

Cement

4. *Cement.*—The cement should meet the requirements of the standard specifications for Portland Cement of the American Society for Testing Materials, and adopted by this Institute. (Standard No. 1.)

Fine Aggregate

5. *Fine Aggregate.*—Fine aggregate should consist of sand, or screenings from crushed stone or crushed pebbles, graded from fine to coarse, passing when dry a No. 8 screen. Fine aggregate should preferably be of silicious materials, clean, coarse, and free from loam, vegetable, or other deleterious matter.

Note.—The paragraphs relating to materials are sufficiently specific as to the quality of the stucco ingredients. However, reference may be made to the recently developed colorimetric test for detecting the presence of organic matter in sands, a description of which is to be found in the report of Committee C-9, American Society for Testing Materials, 1919.

6. *Hydrated Lime.*—Hydrated lime should meet the requirements of the standard specifications for hydrated lime of the American Society for Testing Materials. **Hydrated Lime**

> *Note.*—Hydrated lime should be specified to the exclusion of lump lime, chiefly for the reason that lime which is slaked on the job cannot as a rule be so thoroughly hydrated and so thoroughly mixed in the mortar as the mechanically hydrated product.

7. *Hair or Fiber.*—There should be used only first quality long hair, free from foreign matter, or a long fiber well combed out. **Hair or Fiber**

8. *Coloring Matter.*—Only mineral colors should be used which are not affected by lime, Portland cement, or other ingredients of the mortar, or the weather. **Color**

9. *Water.*—Water should be clean, free from oil, acid, strong alkali or vegetable matter. **Water**

10. *Lath.*—(a) Metal lath should be galvanized or painted expanded lath weighing not less than 3.4 lb. per sq. yd. **Lath**

(b) Wire lath should be galvanized or painted woven wire lath, not lighter than 19-gage, 2-½ meshes to the in., with stiffereners at 8 in. centers.

(c) Wood lath should be standard quality, narrow plaster lath 4 ft. long and not less than ⅜ in. thick.

> *Note.*—The use of wood lath as a base for stucco finds many advocates and many opponents, but the committee does not feel that it can recommend wood lath for cement stucco. More field and test data should be available before the evidence for and against wood lath can be carefully weighed. Further information is desired in regard to the type of wood lath best suited for cement stucco. In some of the most satisfactory work reported by the committee the lath were of phite pine 1 in. wide and ½ in. thick. Both materials and size were here unusual, but the committee is of the opinion that this type of narrow lath is worthy of consideration. For want of information as to the practicability of specifying any particular kind of wood and unusual dimensions, no change is suggested at the present time. It may be stated, however, that nearly all of the test panels of wood lath erected at the Bureau of Standards developed large cracks, in such manner as to suggest that narrower lath (those used were 1⅜ in. wide) with wider keys and heavier nailing would have given better results. The tests also indicate that counter lathing in which the lath are applied lattice fashion produces no more satisfactory results than plain lathing. In view of the much greater cost of counter lathing the committee recommends that reference to this type of application be omitted from specifications.

III. DESIGN.

A. Masonry Walls.

Tile

11. *Tile.*—Tile for exterior walls should preferably be not less than 8 in. thick, and should be hard-burned, with dovetail or heavy ragged scoring. Tile should be set in cement mortar composed of one part cement, not more than one-fifth part hydrated lime, and three parts sand, by volume. The blocks should not vary more than ½ in. in total thickness and should be set with exterior faces in line. Joints should not be raked, but mortar should be cut back to surface. Neither wire mesh nor waterproofing of any type should be applied to tile walls before plastering, nor should any wooden members (except inserts for nailing) be embedded in masonry walls, particularly where they are to be covered with stucco. The surface of the tile should be brushed free from all dirt, dust and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

Brick

12. *Brick.*—Surface brick should be rough, hard-burned, commonly known as arch brick. Brick should be set in cement mortar with joints not less than ⅜ in. thick, and the mortar should be raked out for at least ½ in. from the face. The surface of the brick should be brushed free from all dust, dirt and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

Old brick walls which are to be overcoated should have all loose, friable, or soft mortar removed from joints, and all dirt and foreign matter should be removed by hacking, wire brushing or other effective means. Surfaces that have been painted or waterproofed should be lathed with metal lath before overcoating.

Concrete

13. *Concrete.*—Monolithic concrete walls should preferably be rough and of coarse texture, rather than smooth and dense, for the application of stucco. Walls of this type should be cleaned and roughened, if necessary, by hacking, wire brushing, or other effective means. The surface of the concrete should be brushed free from all dust, dirt, and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

Concrete Block

14. *Concrete Block.*—Concrete block for stucco walls should be rough and of coarse texture, but not weak or friable. Block should be set with cement mortar joints, which should be raked out or cut back even with surface. Before applying the stucco the surface should be brushed free from all dust, dirt, and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

Note.—Buildings of hollow terra cotta tile, brick, concrete, concrete block, and similar materials, are particularly well adapted for the application of stucco because of their rigidity. This, however, depends upon good, solid footings or foundation, a requirement which should be met in all types of stucco structures. Masonry walls should also provide a good surface for the bond or adhesion of the stucco, and wherever possible this bond should be insured by some form of mechanical key. For this reason raking out the joints in a brick wall is recommended as an added precaution, anl similarly walls of concrete or concrete block should not be too smooth, but preferably rough and of coarse texture.

It is most important that masonry walls be clean before the stucco is applied, as otherwise the bond of the stucco cannot be relied upon to stand the strain set up by moisture and temperature changes. Many a failure of stucco on masonry foundations has been attributed to frost action, when the primary cause of the failure has been lack of care in thoroughly cleaning the walls from dirt. Without secure and positive anchorage under such conditions the stucco cannot endure.

Special attention should be callel to the importance of properly wetting the surface of masonry walls just before applying the stucco. Too dry a surface will absorb the water from the fresh plaster coat before the latter has had time to harden properly. On the other hand, a surface completely saturated has lost all its absorptive power, or "suction," a slight degree of which is necessary for best results. A moderate amount of suction tends to draw the fine cement particles into the pores and interstices of the surface; upon this action the bond of the stucco depends. If this bond is to be as strong as possible, the surface should be neither dry nor completely saturated.

Wood lintels over openings in masonry walls should not be used. When old masonry walls are overcoated special attention is called to the necessity for obtaining thorough cleanliness, a good mechanical bond, and proper suction. When any of these conditions are in doubt the walls should be furred and lathed.

B. Frame Walls.

15. *Framing.*—Studs spaced not to exceed 16 in. centers should be run from foundation to rafters without any intervening horizontal members. The studs should be tied together just below the floor joists with 1x6 in. boards which should be let into the studs on their inner side, so as to be flush and securely nailed to them. These boards will also act as sills for the floor joists, which, in addition, should be securely spiked to the side of the studs. **Framing**

16. *Bracing.*—(a) The corners of each wall should be braced diagonally with 1x6 in. boards let into the studs on their inner side, and securely nailed to them. **Bracing**

(b) In back-plastered construction in which sheathing is omitted, at least once midway in each story height, the studs should be braced horizontally with 2x3 in. bridging set 1 in. back of the outside face of the studs. This assumes that the studs are 2x4 in. Larger sizes would require correspondingly larger bridging.

(c) In sheathed construction bridging is not usually used.

Note.—Good bracing of the frame is important to secure the necessary rigidity. Bridging between the studs at least once in each story height is recommended whether the frame is to be sheathed or not. In the former case the bridging should be of the same size as the studs (usually 2x4 in.). Bridging is advisable as an auxiliary fire-stop because of the greater amount of combustible material in the wall as compared with back plastered construction. In the back-plastered type of construction where sheathing is not used, bridging is required for stiffening the frame, and should be 1 in. less than the studs in depth. It should be placed horizontally, and 1 in. back of the outside face of the studs, in order that the back-plaster coat may be carried past the bridging without break at this point. Diagonal bracing at the corners of each wall is recommended, especially when sheathing is omitted. Such bracing may be of 1x6 in. boards, 6 or 8 ft. long, let into the studs on their inner side in order not to interfere with the back plastering or the interior plastering. The length of the corner bracing will, of course, depend to some extent on the location of window or other openings.

The committee feels that fire protection is an important feature of this type of structure, and that some form of fire stop is necessary to develop its full fire-resistive value. Probably the best method is to form a basket of metal lath to occupy the spaces between the studs at the juncture of the floor joists and wall. This should be filled with cement mortar or concrete from the ceiling level to 4 in. above the floor level.

A preliminary report from the Underwriters' Laboratories on back-plastered metal lath and stucco construction with portland cement indicates that "this finish can be expected to furnish a substantial barrier to the passage of flame into the hollow spaces back of it and to provide sufficient heat insulation to prevent the ignition of the wooden supports to which it is attached for about one hour when exposed to fire of the degree of severity to which stucco-finished buildings are likely to be subjected under average exterior fire exposures."

In view of tests and experience with back plastered construction, city ordinances containing restrictions as to its use and requiring sheathing should be changed accordingly.

The committee wishes to recognize the development of metal lumber for frame construction, and believes its merits are such that its use will undoubtedly largely increase. Detailed reference to this form of construction will be made in subsequent additions to this recommended practice.

Sheathing 17. *Sheathing.*—(a) In back-plastered construction the lath should be fastened direct to the studding and back-plastered, and no sheathing is used.

(b) In sheathed construction the sheathing boards should not be less than 6 in. nor more than 8 in. wide, dressed on one or both sides to a uniform thickness of 13/16 in. They should be laid horizontally across the wall studs and fastened with not less than two 8d nails at each stud.

Note.—When sheathing is used it should be laid horizontally and not diagonally across the studs. The stucco test panels erected at the Bureau of Standards in 1915 and 1916 have demonstrated conclusively that diagonal sheathing tends to

crack the overlying stucco by setting up strains in the supporting frame. The result is undoubtedly due to the shrinkage of the sheathing, and whatever benefit might be anticipated from the more effective bracing provided by diagonal sheathing appears to be more than offset by the shrinkage effect. Diagonal sheathing is also less economical than horizontal sheathing, both in material and labor.

18. *Inside Waterproofing.*—(a) In back-plastered construction no waterproofing is necessary. **Inside Waterproofing**

(b) In sheathed construction, over the sheathing boards should be laid in horizontal layers, beginning at the bottom, a substantial paper, well impregnated with tar or asphalt. The bottom strip should lap over the baseboard at the bottom of the wall, and each strip should lap the one below at least 2 in. The paper should lap the flashings at all openings.

Note.—Waterproofing of the faces of the studs in back-plastered construction seems to be ineffective and unnecessary, and its elimination is recommended.

19. *Furring.*—(a) Metal lath. When furring forms an integral part of the metal lath to be used, then separate furring as described in this paragraph is omitted. **Furring**

(b) In back-plastered construction ⅜ in. crimped furring, not lighter than 22-gage or other shape giving equal results, should be fastened direct to the studding, using 1¼ in. x 14-gage staples spaced 12 in. apart.

(c) In sheathed construction ⅜ in. crimped furring not lighter than 22-gage, or other shape giving equal results, should be fastened over the sheathing paper and directly along the line of the studs, using 1¼ in. x 14-gage staples spaced 12 in. apart. The same depth of furring should be adhered to around curved surfaces, and furring should be placed not less than 1½ in. nor more than 4 in. on each side of and above and below all openings.

(d) Wood Lath. Furring 1x2 in. should be laid vertically 12 in. on centers over the sheathing paper and nailed every 8 in. with 6d nails.

Note.—The proper type and depth of furring is a question on which information is desired. If metal lath is applied over sheathing and the commonly recommended practice of filling with mortar the space between lath and sheathing is to be followed, there seems to be no good reason for using furring deeper than ⅜ in. On the other hand, 1x2 in. wood furring is widely used for both metal and wood lath, and there are good arguments both for and against this type of furring. The question of the proper length and gage of staples for metal lath is involved with that of furring. The entire subject needs investigation.

IV. CONSTRUCTION.

A. Preparation of Surface.

20. *Application of Lath.*—(a) Metal Lath. Lath should be placed horizontally, driving galvanized staples 1¼ in. by 14-gage not more than 8 in. apart over the furring or stiffeners. Vertical laps should occur at **Application of Lath**

supports, and should be fastened with staples not more than 4 in. apart. Horizontal joints should be locked or butted and tightly laced or properly tied with 18-gage galvanized wire.

(b) Wood Lath. Lath should be placed horizontally on the furring with ½ in. openings between them. Joints should be broken every twelfth lath. Each lath should be nailed at each furring with 4d nails.

Note.—The results of tests and field observations indicate that more attention should be given to the application of lath to exterior surfaces. Cracks frequently develop in stucco overlaps or at junctions of metal and wire lath, indicating a weakness at these points. This may be due in part to reduced thickness of the stucco where the lath is lapped, or to insufficient tying and fastening at the joints. The ideal job of lathing would obviously be that in which the lath forms a uniform fabric over the structure, without seams or lines of weakness, and with equal reinforcing value in all directions. The ideal condition cannot be realized, but evidence is at hand to indicate that butted and laced or well-tied horizontal joints are better than lapped joints, and in the case of ribbed lath that carefully locked joints are better than lapped joints. Vertical joints must almost of necessity be lapped, but the joints may be made secure if they occur over supports and are well stapled at frequent intervals. The reinforcement obtained by the use of metal lath around corners over wood lath is important on both interior and exterior angles.

Corners

21. *Corners.*—(a) Metal Lath. The sheets of metal lath should be folded around the corners a distance of at least 3 in. and stapled down, as applied. The use of corner bead is not recommended.

(b) Wood Lath. At all corners a 10-in. strip of galvanized or painted metal lath should be firmly stapled over the lath with 1¼ in. by 14-gage galvanized staples.

Spraying

22. *Spraying.*—Before applying the first coat of plaster, wood lath should be thoroughly wetted, but water should not remain standing on the surface of the lath when the plaster is applied.

Insulation

23. *Insulation.*—The air space in back-plastered walls may be divided by applying building paper, quilting, felt, or other suitable insulating material between the studs, and fastening it to the studs and bridging by nailing wood strips over folded edges of the material. This insulation should be so fastened as to leave about 1 in. air space between it and the stucco. Care should be taken to keep the insulating material clear of the stucco, and to make tight joints against the wood framing at the top and bottom of the space and against the bridging.

Note.—At the present time the warmth of the back-plastered stucco house in comparison with that of the sheathed house is questioned by some, but the available evidence seems to indicate that where insulation has been provided as specified, generally satisfactory results have been obtained.

Ordinary building paper applied in a double layer is recommended as a satisfactory insulating medium.

In this connection reference may be made to a series of tests conducted in 1919 at the Armour Institute of Technology, Chicago, to determine the relative heat conductivity of various types of walls. These tests indicated that by the use of building paper or quilting the loss of heat through a stucco wall of the back-plastered type was less, under standardized conditions, than the loss through the ordinary wood frame wall, covered with sheathing and drop siding. A complete report of these tests may be obtained on application to the Commissioner, Associated Metal Lath Manufacturers, Chicago, Ill.

24. *Overcoating.*—Old frame walls which are to be overcoated should be made structurally sound in every respect, and, as far as possible, the general conditions on pages 1 and 2 should be observed; otherwise the recommended practice for frame structures obtains. **Overcoating**

B. Preparation of Mortar.

25. *Mixing.*—(a) The ingredients of the mortar should be mixed until thoroughly distributed, and the mass is uniform in color and homogeneous. The quantity of water necessary for the desired consistency should be determined by trial, and thereafter measured in proper proportion. **Mixing**

(b) Machine Mixing. The mortar should preferably be mixed in a suitable mortar-mixing machine of the rotating drum type. The period of machine mixing should be not less than 5 minutes after all the ingredients are introduced into the mixer.

(c) Hand Mixing. The mixing should be done in a water-tight mortar box, and the ingredients should be mixed dry until the mass is uniform in color and homogeneous. The proper amount of water should then be added and the mixing continued until the consistency is uniform.

26. *Measuring Proportions.*—Methods of measurement of the proportions of water should be used which will secure separate uniform measurements at all times. All proportions stated should be by volume. A bag of cement (94 lb. net) may be assumed to contain 1 cu. ft.; 40 lb. may be assumed as the weight of 1 cu. ft. of hydrated lime. Hydrated lime should be measured dry, and should not be measured nor added to the mortar in the form of putty. **Measuring**

27. *Retempering.*—Mortar which has begun to stiffen or take on its initial set should not be used. **Retempering**

28. *Consistency.*—Only sufficient water should be used to produce a good workable consistency. The less water the better the quality of the mortar, within working limits. **Consistency**

Note.—The importance of proper and thorough mixing of the ingredients of the mortar cannot be too strongly emphasized. Machine mixing is in all cases to be recommended in preference to hand mixing. The use of hair or fiber is considered optional, and when used the method of incorporation should be such as to insure good distribution and freedom from clots. The mainte-

nance of proper and uniform consistency should be insured by measurement of the water as well as of the other ingredients of the mortar. The question of retempering mortar is one which will bear further investigation. At the present time sufficient information is not available to warrant a change in the paragraph on retempering.

Mortar

29. *Mortar.*—All coats should contain not less than 3 cu. ft. of fine aggregate to 1 sack of portland cement. If hydrated lime is used it should not be in excess of one-fifth the volume of cement. Hair or fiber should be used in the scratch coat only on wood lath, on metal or wire lath that is to be back-plastered, or on metal or wire lath which is applied over sheathing and is separated therefrom by furring deeper than ⅜ in.

Application

30. *Application.*—(a) The plastering should be carried on continually in one general direction without allowing the plaster to dry at the edge. If it is impossible to work the full width of the wall at one time, the joining should be at some natural division of the surface, such as a window or door.

(b) The first coat should thoroughly cover the base on which it is applied and be well troweled to insure the best obtainable bond. Before the coat has set it should be heavily cross-scratched with a saw-toothed metal paddle or other suitable device to provide a strong mechanical key.

(c) The second coat should be applied whenever possible on the day following the application of the scratch coat. The first coat should be dampened if necessary, but not saturated, before the second coat is applied. The second coat should be brought to a true and even surface by screeding at intervals not exceeding 5 ft., and by constant use of straightening rod. When the second coat has stiffened sufficiently, it should be dry floated with a wood float and lightly and evenly cross-scratched to form a good mechanical bond for the finish coat. The day following the application of the second coat, and for not less than three days thereafter, the coat should be sprayed or wetted at frequent intervals and kept from drying out.

(d) In back-plastered construction the backing coat should preferably be applied directly following the completion of the brown coat. The keys of the scratch coat should first be thoroughly dampened, and the backing coat then well troweled on to insure filling the spaces between the keys and thoroughly covering the back of the lath. The backing coat should provide a total thickness of plaster back of the lath of ⅝ in. or ¾ in., and should finish about ¼ in. back of the face of the studs.

(e) The finish coat should be applied not less than a week after the application of the second coat. Methods of application will hereinafter be described under "finish."

Note.—Practice varies widely in the mixture and application of stuccos. The use of hair, lime, and waterproofing materials, the variations in the mixtures for the different coats, the number and thickness of the coats, the intervals between the coats, the degree of wetting of the undercoats, and the precautions necessary in protecting the coats from too rapid drying, are details subject to question, and all will stand further investigation. However, the study of the experimental panels

at the Bureau of Standards has yielded considerable information on some of these points.

One of the most important indications from these panels is that lean mixtures containing well-graded aggregate give better results than those commonly specified. Mixtures as lean as one part of cement to six or seven parts of graded aggregate have given excellent results in these tests. The committee is of the opinion that the volume change on rich mortars is accountable for much of the unsightly cracking of stuccos, and that no mixture should be used in which the proportion of cement is greater than one part to three parts of fine aggregate.

The effect of hydrated lime in cement stucco has also been given considerable attention, and the conclusion which is forcing itself upon the committee is that hydrated lime does not improve the structure of the stucco, but by imparting better working quality to the mortar reduces the cost of application. On the other hand, there is evidence that no more than 20% of hydrated lime, by volume of the cement, should be addel to cement stucco if the best results are to be obtained.

There seems to be no good reason for varying the composition of the different coats, but if a variation is to be specified. the scratch coat should logically be the strongest mixture, followed by a leaner brown coat and a still leaner finish. No greater mistake has ever been made in stucco application than the use of a strong brown coat over a weak base or a weak scratch coat. The not uncommon practice of applying a strong brown coat over a lime mortar scratch coat has been responsible for many stucco failures.

The suggestion that the finish coat should logically be leaner than the undercoat immediately brings up the waterproofing question. There are two fundamental points to be considered in this connection; first, that the lean coat is not necessarily lacking in density, and second, that the waterproofing problem in good cement stucco is not one of overcoming permeability, but rather of reducing absorption. The entire question hinges upon absorption, and the evidence at hand indicates that a moderate degree of absorption is a much more preferable condition than a surface covered with craze and map cracks, produced by the use of a too rich or wrongly manipulated finishing coat. Any waterproofing treatment that alters the natural texture and color of the stucco may be dismissed from consideration, and the merit of any integral waterproofing in stucco is exceedingly difficult to determine.

Note.—The question as to number and thickness of coats may be best answered by assuming that each coat of stucco has its own particular function. The scratch coat is the first applied, and its purpose is to form an intimate bond and a secure support for the body of the stucco. On metal lath it also serves as a protective coat, and it should therefore be strong and not too lean. The use of hair or fiber is of questionable value. Hair or fiber should not be used when the space back of the lath is to be filled, and is probably not a necessary ingredient in any case. The committee at the present time would sanction its use only in scratch coats on wood lath, or on metal or wire lath that is to be back plastered, or on metal or wire lath that is applied over furring deeper than ⅜ in. The thickness of the scratch coat should average about ¼ in. over the face of the lath.

The function of the second coat (commonly called the brown or straightening coat) is to establish a true and even surface upon which to apply the finish. It forms the body of the stucco, and must fill the hollows and cover the humps of the scratch coat. For this reason an average thickness of ⅜ in. to ½ in. will usually be required. The brown and finish coats, or the scratch and brown coats, are sometimes combined in two-coat work, which is permissible when the base upon which the stucco is applied is fairly true and even, or when, on account of cost consideration, the best obtainable finish is not required. It is difficult, however, to obtain a satisfactory finish on a coat which runs ½ in. or more in thickness, since the tendency of a heavy coat to bag and slip is likely to produce an uneven surface.

The finish coat serves only a decorative purpose and has no structural value. Its function is solely to provide an attractife appearance, and any mixture or any method of application that may detract from the appearance, or in any way injure its permanency, should be avoided. Herein lies the argument for lean mixtures, which are more likely to be free from unsightly defects than rich mixtures, and are also more likely to improve in appearance under the action of the weather. The finish coat should be as thin as possible consistent with covering capacity, and may vary from ⅛ to ⅜ in. in thickness, depending upon the type employed.

It is obvious from the foregoing that first-class stucco should be three-coat work, each coat serving its own particular purpose. The bond between the brown coat and the scratch coat needs to be strong in order to carry the weight of the body of the stucco, and for this reason it is now considered preferable to apply the brown coat the day following the application of the scratch coat. Except in dry or windy weather little wetting of the scratch coat should be necessary when the brown coat is to follow within 24 hours. A slight degree of absorption of "suction" in the scratch coat is probably better than complete saturation, for the brown coat, as well as the others, is necessarily mixed with a larger quantity of water than it requires for maximum strength. The removal of a portion of this excess water by the suction of the undercoat not only improves the quality of the coat, but also insures a better bond by tending to draw the fine particles of the cement into the pores and interstices of the undercoat.

Whereas the interval between the brown coat and scratch coat, as recommended above, is relatively short, the interval before applying the finish coat should be as long as permissible under the conditions of the work. The reason for thus delaying the application of the finish is to enable the body of the stucco to obtain its initial shrinkage and a nearer approach to its final condition of strength and hardness, before being covered with the surface coat. The bond of the latter needs to be intimate rather than of maximum strength and if the body of the stucco has been allowed to thoroughly set and harden, it may be assumed that there is less liability of volume changes in the undercoats to disturb the finish coat. A week or more should elapse between the application of the brown and finish coats.

The finish coat should be applied over a damp but not saturated undercoat, for excess water is likely to injure the bond seriously. Certain types of finish, such as the wet mixtures used for sand spraying, or for the "spatter dash" finish, may preferably be applied to a fairly dry undercoat, since suction

must be depended upon to prevent streakiness and muddy appearance. The fact that finishes of this type applied in this manner may set and dry out with little strength is not serious; they gradually attain sufficient hardness with exposure to the weather.

31. *Two-Coat Work.*—Whenever two-coat work is required, the first coat should preferably be "doubled"—that is, as soon as the first coat is stiff enough it should be followed by a second application of mortar, and this should then be treated as described for the second coat under paragraph 30. The finish should be applied not less than a week after the application of the first coat. **Two-Coat Work**

32. *Drying Out.*—The finish coat should not be permitted to dry out rapidly, and adequate precaution should be taken, either by sprinkling frequently after the mortar is set hard enough to permit it, or by hanging wet burlap or similar material over the surface. **Drying Out**

Note.—Curing of the undercoats by sprinkling and protection of finish coats against the sun, wind, rain and frost by means of tarpaulins are always to be recommended. This is not always feasible, however, and the architect should be content to specify and insist upon reasonable precautions.

33. *Freezing.*—Stucco should not be applied when the temperature is below 32 degrees F., nor under any conditions such that ice or frost may form on the surface of the wall. **Freezing**

Note.—The applications of cement stucco in freezing weather should be avoided, and, in fact, temperatures slightly above the freezing point may allow frost to form on a damp wall. The application of stucco under such conditions is likely to result in failure.

C. *Finish.*

34. *Stippled.*—The finishing coat should be troweled smooth with a metal trowel with as little rubbing as possible, and then should be lightly patted with a brush of broom straw to give an even, stippled surface. **Stippled**

35. *Sand Floated.*—The finishing coat, after being brought to a smooth, even surface, should be rubbed with a circular motion of a wood float with the addition of a little sand to slightly roughen the surface. This floating should be done when the mortar has partly hardened. **Sand Floated**

36. *Sand Sprayed.*—After the finishing coat has been brought to an even surface, it should be sprayed by means of a wide, long-fiber brush—a whisk broom does very well—dipped into a creamy mixture of one part of cement to two or three parts sand, mixed fresh at least every 30 minutes, and kept well stirred. This coating should be thrown forcibly against the surface to be finished. This treatment should be applied while the finishing coat is still moist and before it has attained its early hardening—that is, within 3 to 5 hours. To obtain lighter shades add hydrated lime not to exceed 10% of the weight of the cement. **Sand Sprayed**

Rough-Cast or Spatter Dash

37. *Rough-cast or Spatter Dash.*—After the finishing coat has been brought to a smooth, even surface with a wooden float and before finally hardened, it should be uniformly coated with a mixture of one sack of cement to 3 cu. ft. of fine aggregate thrown forcibly against it to produce a rough surface of uniform texture when viewed from a distance of 20 ft. Special care should be taken to prevent the rapid drying out of this finish by thorough wetting down at intervals after stucco has hardened sufficiently to prevent injury.

Applied Aggregate

38. *Applied Aggregate.*—After the finishing coat has been brought to a smooth, even surface, and before it has begun to harden, clean round pebbles, or other material as selected, not smaller than ¼ in. or larger than ¾ in. and previously wetted, should be thrown forcibly against the wall so as to embed themselves in the fresh mortar. They should be distributed uniformly over the mortar with a clean wood trowel, but no rubbing of the surface should be done after the pebbles are embedded.

Exposed Aggregate

39. *Exposed Aggregate.*—The finishing coat should be composed of an approved, selected coarse sand, crushed marble, or granite or other special material, in the proportion given for finishing coats, and within 24 hours after being applied and troweled to an even surface should be scrubbed with a stiff brush and water. In case the stucco is too hard, a solution of one part hydrochloric acid in four parts of water by volume can be used in place of water. After the aggregate particles have been uniformly exposed by scrubbing, particular care should be taken to remove all traces of the acid by thorough spraying with water from a hose.

Mortar Colors

40. *Mortar Colors.*—When it is required that any of the above finishes should be made with colored mortar not more than 10% of the weight of portland cement should be added to the mortar in the form of finely ground mineral coloring matter.

Note.—A predetermined weight of color should be added dry to each batch of dry fine aggregate before the cement is added. The color and fine aggregate should be mixed together, and then the cement mixed in. The whole should be then thoroughly mixed dry by shoveling from one pile to another through a ¼ in. mesh wire screen until the entire batch is of uniform color. Water should then be added to bring the mortar to a proper plastering consistency.

It is practically impossible to specify in written paragraphs the methods by which successful finishes are obtained. The quality of these depends upon the knowledge and skill of the plasterer, and the specification writer must content himself with a brief description of the several types. In the finishing of stuccos, however, there are certain causes and effects which should be more generally recognized, a brief discussion of which will help to explain the limitation of the commonly used finishes and indicate the methods to be pursued in the attempt to develop better finishes.

In an earlier paragraph the defects resulting from the expansion and contraction of rich mortars have been referred to. The chance of such defects occurring must be greatest in the

finish coat, which is directly exposed to the extremes of moisture and temperature variations. The hope of overcoming these defects lies mainly in the use of leaner mixtures, in which the tendency to movement is cut down as the proportion of cement is reduced. The problem therefore is to use less cement and at the same time retain the necessary density by improved gradation of the aggregate. Considerable success has already attended experiments along this line, and even better results are anticipated in the future.

All that may be accomplished in this direction, however, will hardly permit a smooth troweled finish to be used. This treatment produces a concentration of fine material at the surface, which will almost inevitably develop fine cracks. In the course of time these cracks will collect soot and dirt and become conspicuous and unsightly. At best the smooth troweled finish is not to be recommended, and specifications should eliminate all reference to it.

The dash finishes—such as the sand spray, which is obtained by applying a mixture of sand, cement and water with a whisk broom or long-fiber brush, or the spatter dash, which is usually a thin mortar containing coarse sand or stone screenings thrown from a paddle, or the rough-cast, which is a mixture of pebbles and cement grout thrown from a paddle or the back of a trowel—are all relatively rich in cement and all develop fine cracks to a very marked degree, but the rough texture of the surfaces masks these defects, and the type is therefore generally satisfactory and very widely used. The use of these finishes is in general to be recommended, unless the work is done by a stucco specialist, whose skill and experience qualify him to execute the more difficult finishes to be discussed in the following paragraphs.

The chief objection to the dash finishes as above described is their rather cold, unbroken cement color, which may be relieved and improved to a considerable extent by the judicious use of mineral pigments. Another means of varying the monotony of the natural grays and whites of the cement is by the use of the dry dash finishes, in which clean pebbles or stone chips are thrown against the fresh mortar of the finishing coat while it is still soft. When the dry dash is well selected, and the particles thickly and uniformly distributed over the surface, the finish thus obtained is pleasing and possesses decidedly more life and character than the wet dashes.

The sand-float finish deserves special consideration because it promises to be one of the most satisfactory finishes of the future. Due to the use of rich mixtures the sand-float finish has usually developed defects similar to those experienced with the smooth troweled finishes, differing from the latter only in degree. Sand-floated stuccos which have been covered with paint are to be found in every community, and this alone is sufficient evidence of unskilled manipulation of this finish and of the unsatisfactory results that have been obtained. In the experiments carried out at the Bureau of Standards, the sand-float finish was found to be most satisfactory on mixtures containing not more than 1 part of portland cement to 4 parts of fine aggregate, and mixtures as rich as 1 : 3, with a small addition of hydrated lime, were satisfactory as a rule only when the final floating was delayed until the mortar had well stiffened. In this manner the concentration of fine material in the surface was prevented. This experience confirms the necessity for using

leaner mixtures than have been specified heretofore, and for rmoving the cement from the surface by mechanical or other means, if the sand-float finish is to come into its own.

There is no hard and fast line between the sand-float finish and the exposed aggregate finish, since in the final water-floating process of the former the aggregate is left sufficiently exposed to modify and improve the tone of the finished wall. When the sand-floated surface is further improved by an acid wash the grains of the aggregate are cleanly exposed. It seems preferable in classification, however, to limit the exposed aggregate finishes to those in which coarser aggregates are employed than would be feasible for the sand-float finish. Thus defined, the exposed aggregate finish is obtained by the application of a coarser mortar containing carefully selected and graded aggregates, so that when the latter are exposed by brushing and cleaning the resulting texture resembles that of cast concrete which has been subjected to similar surface treatment. One of the members of the committee has developed a stucco of this type which has been applied to the Field House in East Potomac Park, Washington, D. C., over terra cotta tile. The color and texture of this finish, produced entirely by the aggregate, is the same as that of the concrete trim of the building. At the present time only the wings of this structure are completed, but the work thus far marks a distinct step in advance, not only in the treatment of the stucco, but also in the general adaptation of surface-treated concrete to exacting requirements.

In conclusion, the committee desires to state its conviction that while portland cement stucco may develop certain small defects which cannot always be guarded against, the product may be depended upon, if applied in accordance with the accompanying recommended practice, to be structurally sound, durable, and capable of giving satisfactory service, with little or no outlay for repairs or maintenance. The committee believes, however, that assurance of satisfactory results in stucco depends largely on the development of stucco specialists, experienced and skilled in this particular art, as distinguished from ordinary plastering. Intelligent and high-class workmanship is so essential to good stucco that only those contractors who have had sufficient experience to establish their own confidence in the product, and who are willing to guarantee their work, should be employed for its application.

TENTATIVE STANDARD SPECIFICATIONS FOR CONCRETE FLOORS.*

I. Application and Use

A. FOREWORD

These "Standard Specifications for Concrete Floors" of the American Concrete Institute, with supplementary notes explaining and amplifying the specifications were prepared by the Committee on Concrete Floor Finish. The specifications are printed on the left hand pages and the notes on the right hand pages, in order to facilitate cross reference.

B. APPLICATION OF SPECIFICATIONS

These specifications apply to floors in buildings, whether subjected to moderate or heavy traffic, and cover the laying and finishing of the floor; also its protection during early hardening.

C. USE OF SPECIFICATIONS

For architects, engineers and others desiring to embody these specifications in their general specifications covering a particular piece of work, the following outline of the paragraphs necessary to meet different conditions will prove convenient:

Floors Laid on Ground:—Moderate or Light Traffic.
Two-Course—Paragraphs 1-19 (except 8); 34-52; 54-57.
One-Course—Paragraphs 1-19 (except 8); 34-47; 58-62.

Floors Laid on Ground:—Heavy Traffic.
Two-Course—Paragraphs 1-19; 34-51; 53-57.

Reinforced-Concrete Floors:—Moderate or Light Traffic,
Paragraphs 1-26 (except 8); 28-33.

Reinforced-Concrete Floors:—Heavy Traffic: Paragraphs 1-25; 27-33.

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* As printed in Proc., A.C.I., vol. XIV, 1918, p. 496, with revisions printed in Proc. A.C.I., vol. XV, 1919, p. 413, and as revised by Committee C-2 on Concrete Floor Finish 1922. Accepted by Annual Meeting, January, 1923.

II. MATERIALS

A. PORTLAND CEMENT

Portland Cement 1. Portland cement shall meet the requirements of the current Standard Specifications for Portland Cement adopted by the American Society for Testing Materials.

B. AGGREGATES

General Requirements 2. Before delivery on the job, the contractor shall submit to the architect or engineer a fifty (50) lb. sample of each of the aggregates proposed for use. These samples shall be tested, and if found to pass the requirements of the specifications, similar material shall be considered as acceptable for the work. In no case shall aggregate containing frost or lumps of frozen material be used.

Crusher run stone, bank run gravel or mixtures of fine and coarse aggregate prepared before delivery on the work shall not be used.

C. FINE AGGREGATE

General Requirements 3. Fine aggregate shall consist of natural sand or screenings from hard. tough crushed rock or gravel consisting of quartz grains or other hard material, clean and free from any surface film or coating and graded from fine to coarse, with the coarse particles predominating.

Grading 4. Fine aggregate, when dry, shall pass a screen having four (4) meshes to the linear inch; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear inch and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch.

Impurities 5. Fine aggregate shall not contain injurious vegetable or other organic matter as determined by the colorimetric test nor more than five (5) per cent by volume of clay or loam. Field tests may be made by the architect or engineer on fine aggregate as delivered at any time during the progress of the work. If there is more than seven (7) per cent of clay or loam by volume in one (1) hour's settlement after shaking in one hundred (100) per cent excess of water, the material represented by the sample shall be rejected.

Mortar Strength Test 6. Fine aggregate shall be of such quality that mortar composed of one (1) part portland cement and three (3) parts fine aggregate, by weight, when made into briquets, shall show a tensile strength at seven (7) and twenty-eight (28) days at least equal to the strength of briquets composed of one (1) part of the same cement and three (3) parts standard Ottawa sand, by weight. The percentage of water used in making the briquets of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand briquets of standard consistency. In other respects all briquets shall be made in accordance with the methods of testing cement recommended by the American Society for Testing Materials. (See Standard Specifications and Tests for Portland Cement of the A. S. T. M. Serial Designation C 9-21.)

II. MATERIALS

Aggregates. Many kinds of stone, from very hard quartzite to soft limestone, are crushed to the required sizes and used as concrete aggregates. Similarly, many varieties of pebbles are used. The natural tendency is to use materials at hand; but if aggregates are not of good quality or if they contain too much clay or other impurities, a poor concrete will result. Hence it is highly important that the aggregates be tested unless their quality is known.

The use of frozen aggregates results in very inferior concrete. Lumps of ice and frozen gravel go through the mixer and into the forms without being combined with the cement. When they thaw out, voids or stone pockets are left in the concrete.

Aggregates are usually considered as belonging to one of two classes: Fine aggregate, composed of sand or stone screenings, and coarse aggregate, composed of crushed stone or pebbles, the line of division, purely an arbitrary one, being marked by the screen having ¼-in. meshes. This division provides a simple and customary means of properly proportioning the aggregate as a whole.

Unwashed materials may contain clay or organic impurities, comparatively small amounts of which may have ruinous effects on concrete. More than seven (7) per cent of clay by volume may cause a serious loss of strength of the concrete, while even smaller amounts if present as a surface film on the particles, reduce the strength of concrete by preventing proper bonding with the cement. A recent series of tests at the Structural Materials Research Laboratory showed that the presence of organic matter to the extent of only 1/1000 part of the weight of the fine aggregate may decrease the strength of the resulting concrete by twenty-five (25) per cent. The field test for clay or loam and the colorimetric test for organic matter are simple methods for determining the presence of such impurities.

The colorimetric test may be applied in the field as follows: Fill a twelve (12) ounce graduated prescription bottle to the four and one-half (4½) ounce mark with the sand to be tested. Add a three (3) per cent solution of sodium hydroxide until the volume of sand and solution, after shaking, amounts to seven (7) ounces. Shake thoroughly and let stand for twenty-four (24) hours. The sample shall then show a practically colorless solution, or at most a solution not darker than straw color.

The hardness of the aggregate is a feature to be considered, but it is of lesser importance in influencing the strength or resistance to abrasion of concrete, than the methods of mixing and placing and of protecting the floor during the early hardening period. However, where great resistance to abrasion is essential, as in the construction of floors that will be subjected to heavy trucking, the hardness of the aggregate (particularly for the wearing course, if there is one) becomes most important, and in such cases the use of small pebbles or small pieces of hard crushed rock (No. 1 aggregate for wearing course) is desirable. If used in the proportions given in paragraph 27, such aggregate will help to produce a harder and more wear-resistant surface.

To secure good concrete the coarse aggregate should have a maximum size of approximately two (2) inches for plain concrete and 1 in. for reinforced work. Slabs less than four (4) inches thick

D. COARSE AGGREGATE

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7. Coarse aggregate shall consist of clean, hard, tough, crushed rock or pebbles graded in size, free from vegetable or other organic matter, and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall range from one and one-half (1½) in. down, not more than five (5) per cent passing a screen having four (4) meshes per linear inch, and no intermediate sizes shall be removed.

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8. No. 1 aggregate for the wearing course shall consist of clean, hard, tough, crushed rock or pebbles, free from vegetable or other organic matter, and shall contain no soft, flat or elongated particles. It shall pass when dry a screen having three-eighths (⅜) in. openings and not more than ten (10) per cent shall pass a screen having four (4) meshes per linear inch.

E. WATER

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9. Water shall be clean, free from oil, acid alkali or vegetable matter.

F. COLOR

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10. If artificial coloring matter is required, only those mineral colors shall be used which, in the amount hereinafter specified, will not appreciably impair the strength of the cement.

G. REINFORCEMENT

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11. The reinforcing metal shall meet the requirements of the current Standard Specifications for Steel Reinforcement of the American Society for Testing Materials. It shall be free from excessive rust, scale, paint or coatings of any character which will tend to reduce or destroy the bond.

H. JOINT FILLER

int Filler

12. The joint filler shall be a suitable compound that will not become soft and run out in hot weather, nor hard and brittle and chip out in cold weather; or, prepared strips of fiber matrix and bitumen as approved by the architect or engineer. The strips shall be one-half (½) in. in thickness and their width shall at least equal the full thickness of the slab.

III. CONSTRUCTION

A. PROPORTIONING

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13. The method of measuring the materials for the concrete or mortar, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A sack of portland cement (94 lb. net) shall be considered as one (1) cu. ft.

and heavily reinforced may require ¾ in. as a maximum. A well graded coarse aggregate generally produces a denser and stronger concrete than an aggregate of uniform size.

Mixed Aggregate. Sand and pebbles from a pit, or crushed stone from a crusher are seldom if ever properly graded for use in concrete. There is nearly always a surplus of fine material from a pit and of coarse material from a crusher. That is, if one hundred (100) cu. ft. of material from a gravel pit is passed over a one-fourth (¼) in. screen, perhaps seventy (70) cu. ft. will pass through and forty (40) cu. ft. will be retained on the screen. If a proper gradation is obtained by the use of two (2) cu. ft. of fine with four (4) cu. ft. of coarse material, only 20 cu. ft. of the fine material should be used with the forty (40) cu. ft. of pebbles retained on the screen. If the bank-run material were used, the resulting proportion would be seven (7) to four (4) instead of two (2) to four (4). This is the fundamental objection to the use of bank-run material, and a similar objection applies to crusher run material.

Prepared aggregate mixtures, which are sometimes supplied in carload lots, develop the same objections because coarse and fine materials become somewhat separated in transit so that no two individual wagon loads taken from the car will have the same relative proportions of fine and coarse aggregate. It is far better to handle the fine and coarse materials separately and combine them in proper amounts *at the mixer.*

Water. A safe rule for mixing concrete is to use only water which is fit to drink.

Color. Mineral coloring material is preferred to organic coloring material, because the latter fades more than mineral colors, and because it may seriously reduce the strength of the concrete. Mineral coloring may reduce the strength of concrete somewhat but where the quantities used are less than 5 per cent, this is not serious. The use of colored aggregates is preferable in obtaining color effects, the surface of the floor being brushed or ground to expose the aggregate.

MEASURING AND MIXING

Proportioning. Uniform proportioning, and uniform consistency of concrete are essential for high grade floor construction. If wheelbarrows are used to measure the aggregates, a simple method should be provided to check occasionally the amounts in the barrows. Boxes made to set in the barrows and holding one or more cubic feet are useful. Some barrows are built with level tops so that they may be struck off to known capacity. A small tank capable of delivering a fixed volume of water for each batch insures a more nearly uniform consistency than can be obtained when water is added by means of a pail. Batch mixers are now generally equipped with water measuring devices.

B. MIXING

Machine Mixing

14. All concrete shall be mixed by machine except when the architect or engineer shall otherwise permit under special conditions. A batch mixer of an approved type shall be used. The ingredients of the concrete or mortar shall be mixed to the specified consistency, and the mixing shall continue for at least one (1) minute after all the materials are in the drum. Raw materials shall not be permitted to enter the drum until all the material of the preceding batch has been discharged.

Hand Mixing

15. When it is necessary to mix by hand, the materials shall be mixed dry on a watertight platform, until the mixture is of uniform color, the required amount of water added, and the mixing continued until the mass is of uniform consistency and homogeneous.

Retempering

16. Retempering of mortar or concrete which has partially hardened, that is, mixing with or without additional materials or water, shall not be permitted.

C. CURING

Covering

17. As soon as the finished floor has hardened sufficiently to prevent damage thereby, the floor shall be covered with at least one (1) in. of wet sand, or two (2) in. of sawdust, which shall be kept wet by sprinkling with water for at least ten (10) days.

Protection

18. The freshly finished floor shall be protected from hot sun and drying winds until it can be sprinkled and covered as above specified. The concrete surface must not be damaged or pitted by raindrops, and the contractor shall provide and use when necessary sufficient tarpaulins to completely cover all sections that have been placed within the preceding twelve (12) hours.

D. TEMPERATURES BELOW 40° F.

Temperature below 40 Degrees Fahrenheit

19. If at any time during the progress of the work the temperature is, or in the opinion of the architect or engineer will, within twenty-four (24) hours, drop to 40 degrees Fahrenheit, the water and aggregates shall be heated and precautions taken to protect the work from freezing for at least five (5) days.

Machine Mixing. Concrete must be thoroughly mixed before it is deposited in the forms. Experiments have shown that the strength of concrete increases rapidly with the time of mixing up to one minute. The rate at which the mixer revolves i. e. between 12 and 25 R. P. M. has little influence on the strength of concrete. A small mixer should not be speeded up where it is necessary to place a large volume of concrete in a short time, because insufficient mixing decreases the strength of concrete. If a given mixer cannot mix enough concrete thoroughly in the available time, a second mixer or a larger one should be provided. Continuous mixers do not produce as uniform concrete as do batch mixers and are therefore not recommended.

Hand Mixing. Where large volumes of concrete are to be placed, hand mixing will generally be found more expensive than machine, but good results may be obtained with hand mixing if the specifications are carefully followed.

Retempering. Concrete or mortar should be deposited in place as soon as possible after mixing; otherwise it becomes partially hardened. If that happens it should be thrown out because it will not attain its full strength even if remixed with other materials.

The hardening of concrete is a process which requires time and the presence of moisture. The more thorough the process the harder and stronger the concrete. As mentioned hereafter, it is important that a minimum amount of water be used in mixing the concrete, but after the concrete is deposited in place, it is even more important that its water content be retained and not allowed to drain off or evaporate. Drenching the subbase with water before depositing the concrete reduces the loss of water from below by gravity or capillary action, but that alone is not sufficient: Evaporation from above must also be prevented. A common method of protecting the concrete so as to retain its water content is to cover the surface with damp earth or sawdust as soon as it has hardened sufficiently to prevent injury thereby, and then to keep the sand damp by frequent sprinkling. Where feasible, an excellent method is to build small dams of clay or other suitable material around the floor, and then flood it with a few inches of water. In other cases a covering of *wet* burlap has been found satisfactory. This protection should be continued for at least ten days, and if possible for three weeks. Laboratory tests have shown that protecting the surface of a concrete floor in this manner for the first ten days will increase the compressive strength and resistance to wear fifty (50) per cent. ("Proceedings," American Concrete Institute, 1921, p. 251.) In other words, this one item of ten (10) days' protection will give the owner of a concrete floor fifty (50) per cent greater value for his money. Still better results will be obtained if this protection can be continued for three weeks, or longer if practicable.

Temperature Below 40° F. If concrete is allowed to freeze during the early hardening period, it may be seriously damaged and its hardening will be greatly delayed. Warmth as well as moisture is necessary for the proper hardening of concrete, so that the concrete should have a temperature of at least 60° F. when deposited and provision made to maintain this temperature for at least 5 days.

IV. REINFORCED-CONCRETE FLOORS

For reinforced-concrete floors the following will apply in addition to paragraphs 1 to 19 incl.

A. FORMS

Forms 20. The forms shall be substantial, unyielding and so constructed that the concrete will conform to the designed dimensions and contours, and shall also be tight to prevent the leakage of mortar. The supports for floors shall not be removed until the concrete has hardened sufficiently and then only with the consent of the engineer or architect in charge. Permanent shores shall be placed in such a manner as to assure safety of the floors after temporary supports are removed.

B. REINFORCEMENT.

Reinforcement 21. Reinforcing metal shall be provided as called for on the plans. It shall be placed as indicated and mechanically held in position so that it will not become disarranged during the depositing of the concrete. Whenever it is necessary to splice tension reinforcement, the character of the splice shall be such as will develop its full strength. Splices at points of maximum stress shall be avoided. Splicing by lapping bars without contact and with space between bars along the overlap equal to twice the thickness of the bars is preferable to mechanical splices or clamps.

C. CONCRETE SLAB

Proportions 22. The concrete shall be mixed in the proportions by volume of one (1) sack of portland cement, two (2) cu. ft. of fine aggregate and four (4) cu. ft. of coarse aggregate.

Consistency 23. Only sufficient water shall be used to produce a workable plastic mix, which will flow sluggishly into the forms and around the reinforcement and which can be conveyed from the mixer to the forms without the separation of the coarse aggregate from the mortar.

Placing 24. The concrete shall be placed in a manner to insure a smooth ceiling, and thoroughly worked around the reinforcement and into the recesses of the forms. Concrete shall be deposited in its final position as soon as possible after mixing. It shall be struck off to a surface at least one (1) in. below the established grade of the finished surface of the floor. Workmen shall not be permitted to walk in freshly-laid concrete, and if sand or dust collects on the base, it shall be carefully removed before the wearing course is applied.

Joints 25. When it is necessary to make a joint in a floor slab, its location shall be designated by the architect or engineer; joints to be vertical.

REINFORCED-CONCRETE FLOORS

Forms. When forms carrying concrete floors sag out of place before the concrete has hardened it is very difficult to force them back into position. Therefore, care should be taken before placing is commenced to have the forms and false work of such strength that there is no danger of sagging or failure.

The weight of a reinforced concrete floor is sometimes nearly equal to the load it is expected to carry. If sufficient time is not allowed for hardening there is possibility of failure, whereas an excellent floor would have resulted had it been allowed to harden properly before the supports were removed. This is especially true in cold weather, because concrete, without proper protection hardens very slowly if at all when the temperature is below 40 degrees. Hence it is safe to assume that a concrete floor gains practically no strength during the time exposed to low temperature.

Reinforcement. The value of reinforcing steel depends upon position as well as quantity of steel. The designed strength of a floor is based on the assumption that the steel will be in the position shown on the plans. If the reinforcing is out of place its value will be decreased, or it may be subjected to possible corrosion because of insufficient protecting concrete below. A three-fourth (¾) inch covering should be the minimum and should be increased as conditions may require.

CONCRETE SLAB

Consistency. Few engineers and contractors realize the damage caused by the use of too much water in mixing concrete. The statement is frequently made that excess mixing water does no harm because it soon runs off or evaporates, and that very wet concrete gains strength more rapidly than dry concrete, but this is not correct. A series of tests made at the Structural Materials Research Labratory, Chicago, shows that the quantity of mixing water is probably the most important factor affecting the strength and durability of concrete, and that down to a point lower than can be reached in ordinary concrete work, the smaller the quantity of mixing water, the stronger will be the concrete. The use of one (1) pint more water than necessary in a one (1) bag batch decreases the strength and resistance to wear of the resulting concrete as much as though two (2) or three (3) pounds of cement were left out. Concrete of sloppy consistency has less than half the strength of concrete of the same proportions mixed with the proper amount of water. Therefore the best rule is to use the minimum quantity of water that will produce a workable, plastic, mix.

For reinforced concrete a somewhat wetter consistency is necessary in order that the mixture will settle readily around the reinforcing bars and fill all the spaces between them, but considerably less water should be used than is customary, and much better concrete would then result.

The slump test is a simple method for determining the proper consistency for the work in hand. A frustum of a cone, four (4) ins. in diameter at the top, 8 inches at the bottom and twelve (12) ins. high, made of sheet metal, is filled with the mixture to be tested, the concrete being puddled with a pointed metal rod while the cone is being filled. The cone is immediately lifted off and the settlement or slump noted. For a plain concrete floor slab the proper slump is one (1) in. to one and one-half (1½) to one (1) in., and for a reinforced-concrete floor slab, two (2) in. to two and one-half (2½) in. A greater slump indicates the use of too much water. In some cases where the reinforcement is complicated, the strength may be retained by adding a sufficient amount of cement to keep the water-cement ratio unchanged.

Joints. Floor finish should not be divided or scored or blocked off by scoring tools except at structural expansion joints as this leads to rapid wear when subject to impact of traffic wheels.

D. WEARING COURSE

Proportions and Thickness

26. (Mixture No. 1) The mortar shall be mixed in the proportions of one (1) sack of portland cement, and two (2) cu. ft. of fine aggregate. The minimum thickness shall be three-quarters (¾) in.

27. (Mixture No. 2) The mortar shall be mixed in the proportions of one (1) sack of portland cement, one (1) cu. ft. of fine aggregate and one (1) cu. ft. of No. 1 aggregate for wearing course. The minimum thickness shall be three-quarters (¾) inch.

Consistency

28. The mortar shall be of the dryest consistency possible to work with a sawing motion of the strikeboard.

Placing

29. The wearing course shall be placed immediately after mixing. It shall be deposited on the fresh concrete of the base before the latter has appreciably hardened, and brought to the established grade with a strikeboard.

Note. When placing the wearing course after the concrete slab has hardened, eliminate paragraph 29 and substitute paragraphs 30 and 31.

Preparation of Slab

30. The surface of the slab shall be thoroughly roughened by picking or other means and cleaned of all dirt and debris.

Placing

31. The slab shall be thoroughly moist but free from pools of water when the grout and mortar for wearing course is placed. A neat cement grout shall be brushed on the surface of the slab, the wearing course immediately applied and brought to the established grade with a strikeboard. Grout and mortar shall be used within forty-five (45) minutes after mixing with water.

Finishing

32. After the wearing course has been brought to the established grade by means of a strikeboard, it shall be worked with a wood float in a manner which will thoroughly compact it and provide a surface free from depressions or irregularities of any kind. When required, the surface shall be steel-troweled, but excessive working shall be avoided. A mixture of dry cement, sand and number one aggregate may be applied to the fresh concrete of the base for a wearing course, but in no case shall dry cement or a mixture of dry cement and sand be sprinkled on the surface of the wearing course to absorb moisture or to hasten the hardening. Special methods not conflicting with these specifications may be used.

Coloring

33. If artificial coloring is used, it must be incorporated with the entire wearing course and shall be mixed dry with the cement and aggregate until the mixture is of uniform color. In no case shall the amount of coloring exceed five (5) per cent of the weight of the cement.

WEARING COURSE

Proportions and Thickness. Either of the two (2) mixes specified insures an excellent finish. As indicated in notes on aggregates, however, the No. 2 mixture using small pebbles or stone chips with sand resists abrasion better than No. 1 mixtures and is preferred where the floor will be subjected to heavy traffic.

Consistency. The above remarks on the consistency of the concrete for the slab apply with equal or added force to the wearing course, for this is the part of the floor which must withstand all the abrasive action of traffic.

Placing. Where possible, the wearing course should be placed before the base course has hardened appreciably, because this insures a good bond and a practically monolithic floor. In case this is not possible, or when it is necessary to renew the wearing course on an old floor, the precautions given in paragraphs 30 and 31 should be carefully observed. Failure to do so may cause a poor bond, which may allow the wearing course to work loose from the base, crack and break up under traffic. Roughening the slab gives a mechanical bond. The slab should obviously be free from dirt and refuse. In order to reduce absorption of water from the fresh wearing course, which would prevent it from hardening properly, the slab should be moist, but not covered by a film of water, which might affect the bond. A grout of neat cement painted or brushed into the surface of the slab just before the wearing course is placed insures a thorough bond. Tests made by the Bureau of Standards have shown this to be more effective than special treatments. If these precautions are followed and the surface protected properly while hardening, a satisfactory, wear resistant floor will be secured.

Finishing. Working the surface of a concrete floor with a wood float smooths out any inequalities and compacts the surface without drawing to the top the finer particles of cement and sand. All of this adds to the value of the floor. Working with a steel trowel gives a smoother finish, but excessive troweling tends to bring fine particles in the mixture to the surface. These fine particles are not firmly cemented together and loosen rapidly under traffic, thus causing objectionable dust. The same objectionable feature results from sprinkling dry cement or a dry mixture of cement and sand on the finished surface.

In all cases, as soon as the floor has hardened sufficiently, it should be protected from too rapid drying by a covering of damp sand or by flooding with water.

Reference to special methods will permit the use of the so-called "monolithic method" of finishing concrete floors in buildings, but prohibits the practice of drying up excess water on the surface of a wearing course by dusting on a drier.

Coloring. See previous remarks on page 493.

V. PLAIN CONCRETE FLOORS

For plain concrete floors the following will apply in addition to paragraphs 1 to 29 incl.

A. SUBGRADE

Preparation

34. All soft and spongy places shall be removed and all depressions filled with suitable material which shall be thoroughly compacted in layers not exceeding six (6) in. in thickness. The subgrade shall be thoroughly tamped until it is brought to a firm, unyielding surface.

Deep Fills

35. All fills shall be made in a manner satisfactory to the architect or engineer. The use of muck, quicksand, soft clay, spongy or perishable material is prohibited.

Drainage

36. When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

Depth

37. The subgrade shall not be less than ——— in. below the finished surface of the floor.

Note. Subgrade is to be —— in. below the finished surface of the floor when subbase is not required, and at least —— in. below when subbase is required.

B. SUBBASE

Subbase

(Omit these sections when subbase is not required.)

38. Only clean, hard material, such as coarse gravel or steamboiler cinders, free from ash or particles of unburned coal, shall be used in the subbase.

Thickness

39. The material as specified shall be spread on the subgrade thoroughly rolled or tamped to a surface at least —— in. below the finished grade of the floor. On fills, the subbase shall extend the full width of the fill.

Wetting

40. While compacting the subbase, the material shall be kept thoroughly wet, and shall be in that condition when the concrete is deposited.

C. FORMS

Materials

41. Forms shall be free from warp and of sufficient strength to resist springing out of shape.

Setting

42. The forms shall be well staked or otherwise held to the established lines and grades and their upper edges shall conform to the established grade of the floor.

Treatment

43. All wood forms shall be thoroughly wetted and metal forms oiled or coated with soft soap or whitewash before depositing any material against them. All mortar and dirt shall be removed from the forms that have been previously used.

Subgrade. Where concrete floors are laid directly on the ground, it must be firm and unyielding in order to support the floor properly. Spongy places cause the floor to settle unevenly and crack. If natural drainage is poor so that the subgrade may become saturated with water, a suitable drainage system should be provided, not only to prevent settlement, but also, in the case of basements, to insure watertightness.

If the subgrade is of sand or gravel the floor can be laid directly upon it; otherwise a layer of coarse gravel or steam boiler cinders at least six (6) inches thick should be spread upon the subgrade and thoroughly compacted by wetting and rolling or tamping. A coarse, durable material is obviously necessary for this purpose.

As mentioned on page 11 the subbase should be wet when the concrete is deposited, in order to minimize loss of water from the concrete by absorption.

Forms. Forms for concrete, whether wood or metal, are more easily stripped and leave a smoother finish if they are coated with paraffin or some other oil before the concrete is deposited. Soft soap or whitewash answer the same purpose. For further discussion see page 9.

D. LIMITING CONDITIONS

Size of Slabs

44. The slabs or independently-divided blocks when not reinforced shall have an area of not more than one hundred (100) sq. ft., and shall not have dimensions greater than ten (10) ft. Larger slabs shall be reinforced as hereinafter provided.

Thickness of Floor

45. The thickness of the floor shall be not less than —— inches.

Width and Location of Joints

46. When required by the architect or engineer in charge, a one-half (½) inch space or joint shall be left between the floor and the walls and columns of the building, to be filled with the material before specified under "Joint Filler."

Protection of Edges

47. Where required by the architect or engineer in charge, the edges of the slabs at the joints shall be protected by metal. Unless protected by metal, the upper edges of the slabs shall be rounded to a radius of one-half (½) inch.

VI. TWO-COURSE PLAIN CONCRETE FLOOR

A. CONCRETE BASE

Proportions

48. The concrete shall be mixed in the proportions by volume of one (1) sack of portland cement, two and one-half (2½) cu. ft. of fine aggregate and five (5) cu. ft. of coarse aggregate.

Consistency

49. The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under slight tamping, but which can be handled without causing a separation of the coarse aggregate from the mortar.

Placing

50. After mixing, the concrete shall be handled rapidly and the successive batches deposited in a continuous operation completing individual sections of the required depth and width. Under no circumstances shall concrete that has partly hardened be used. The forms shall be filled and the concrete struck off and tamped to a surface the thickness of the wearing course below the established elevation of the floor. The method of placing the various sections shall be such as to produce a straight, clean-cut joint between them so as to make each section an independent unit. If dirt, sand or dust collects on the base it shall be removed before the wearing course is applied. Workmen shall not be permitted to walk on the freshly laid concrete. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used. In no case shall concrete be deposited upon a frozen subgrade or subbase.

Reinforcement

51. Slabs having an area of more than one hundred (100) sq. ft. shall be reinforced with wire fabric, or with plain or deformed bars. The reinforcement shall have a weight of not less than twenty-eight (28) lb. per one hundred (100) sq. ft. The reinforcement shall be placed upon and slightly pressed in the concrete base immediately after the base is placed. It shall not cross joints and shall be lapped sufficiently to develop the full strength of the metal.

LIMITING CONDITIONS

Size of Slabs. Concrete, like most materials, expands and contracts with changes in temperature. Contraction of a floor laid on the ground induces tensile stresses because of the frictional resistance between the floor and the subbase. Where the floor is not provided with reinforcing, it has comparatively little tensile strength and is liable to crack if the slabs are too great in any dimension. Experience has indicated that 10 feet is the maximum size of floor slab that should be used where exposed to wide temperature changes unless reinforced to resist temperature stresses.

Protection of Edges. In certain conditions where concrete floors are subject to excessive abrasion the edges of slabs are liable to be badly chipped unless protected. For this purpose metal strips or angles are sometimes embedded in the edges of adjacent slabs or the edges rounded off and the crevice filled with a stiff joint filler.

TWO-COURSE PLAIN CONCRETE FLOOR

CONCRETE BASE

Reinforcement. As stated above plain floor slabs of the usual thickness and mixtures should not have dimensions greater than 10 feet between joints in order to insure against cracking caused by the tensile stresses developed by contraction. When it is necessary to place slabs with dimensions greater than 10 feet reinforcement should be provided to resist these tensile stresses. It is apparent that if the reinforcement is allowed to extend through an expansion joint, the purpose of the joint would be defeated, because the metal would prevent any movement at the joint. If reinforcement is not lapped sufficiently at its edges or joints, such joints would be planes of weakness and would allow cracks to form there.

B. WEARING COURSE

Proportions for Mixture No. 1 — 52. The wearing course shall be mixed in the proportions of one (1) sack of portland cement, two (2) cu. ft. of fine aggregate. The minimum thickness shall be three-quarters (¾) inch.

Proportions for Mixture No. 2 — 53. The wearing course shall be mixed in the proportions of one (1) sack of portland cement and one (1) cu. ft. of fine aggregate and one (1) cu. ft. of No. 1 aggregate for wearing course. The minimum thickness shall be three-quarters (¾) inch.

Consistency — 54. The mortar shall be of the dryest consistency possible to work with a sawing motion of the strikeboard.

Placing — 55. The wearing course shall be placed immediately after mixing. It shall be deposited on the fresh concrete of the base before the latter has appreciably hardened, and brought to the established grade with a strikeboard. In no case shall more than forty-five (45) minutes elapse between the time the concrete for the base is mixed and the wearing course is placed.

Finishing — 56. After the wearing course has been brought to the established grade by means of a strikeboard, it shall be worked with a wood float in a manner which will thoroughly compact it and provide a surface free from depressions or irregularities of any kind. When required, the surface shall be steel-troweled, but excessive working shall be avoided. A mixture of dry cement, sand and number one aggregate may be applied to the fresh concrete of the base for a wearing course, but in no case shall dry cement or a mixture of dry cement and sand be sprinkled on the surface of the wearing course to absorb moisture or to hasten the hardening. Special methods not conflicting wi.h these specifications may be used.

Coloring — 57. If artificial coloring is used, it must be incorporated with the entire wearing course, and shall be mixed dry with the cement and aggregate until the mixture is of a uniform color. In no case shall the amount of coloring exceed five (5) per cent of the weight of the cement.

VII. ONE-COURSE FLOOR

Proportions — 58. The concrete shall be mixed in the proportions of one (1) sack of portland cement to not more than two (2) cu. ft. of fine aggregate and not more than three (3) cu. ft. of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half (½) the volume of the coarse aggregate.

A cubic yard of concrete in place shall contain not less than six and eight-tenths (6.8) cu. ft. of cement.

Consistency — 59. The materials shall be mixed with sufficient water to produce a concrete which will hold its shape when struck off with a strikeboard. The consistency shall not be such as to cause a separation of the mortar from the course aggregate in handling.

WEARING COURSE

Many attractive surfaces can be obtained in concrete floors by using colored aggregates or mineral coloring materials with either grey or white portland cement. An infinite variety of patterns can be set into the wearing course by using two or more different mortar mixtures. The Terrazzo or Venetian finish is often used in lobbies, corridors and show rooms. Marble or other small chips are added to the mixture for the wearing course and after it is laid additional chips are strewn upon the surface and rolled in. After the surface has hardened somewhat, it is ground down, thus obtaining a hard, smooth, polished surface consisting mainly of chips, very little of the cement mortar being visible.

A concrete floor can be prepared for dancing by waxing in a manner similar to that used for a wooden floor, or by several applications of liquid soap well rubbed into the floor, or by a special process that drives liquid wax into the concrete. Concrete floors can be protected from the action of acid solutions by several different treatments, the choice depending on local conditions.

One-Course Floor. Although usually a one-course floor cannot be given quite as smooth a surface as a two-course floor or any of the special finishes or treatments, yet where such finishes are not desired, it is considered the better type of floor, because being a monolithic slab, it is stronger structurally, and it can be laid more easily and quickly. In order to obtain a reasonably smooth surface a somewhat richer mixture should be used and more care should be taken with the finishing. If these precautions are observed a satisfactory and durable surface will be secured.

Placing

60. After mixing, the concrete shall be handled rapidly and the successive batches deposited in a continuous operation completing individual sections to the required depth and width. Under no circumstances shall concrete that has partly hardened be used. The forms shall be filled and the concrete brought to the established grade with a strikeboard. The method of placing the various sections shall be such as to produce a straight, clean-cut joint between them so as to make each section an independent unit. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used. Workmen shall not be permitted to walk on the freshly laid concrete. In no case shall concrete be deposited upon a frozen subgrade or subbase.

Reinforcement

61. Slabs having an area of more than one hundred (100) sq. ft., or having any dimensions greater than ten (10) ft., shall be reinforced with wire fabric or with plain or deformed bars. The reinforcement shall have a weight of not less than twenty-eight (28) lb. per one hundred (100) sq. ft. The reinforcement shall be placed upon and slightly pressed into the concrete base immediately after the base is placed. It shall not cross joints and shall be lapped sufficiently to develop the full strength of the metal.

Finishing

62. After the concrete has been brought to the established grade by means of a strikeboard, and has hardened somewhat, but is still workable, it shall be floated with a wood float in a manner which will thoroughly compact it and provide an even surface. When required, the surface shall be steel troweled, but excessive working shall be avoided. Unless protected by metal, the surface edges of all slabs shall be rounded one-half (½) inch.

AMERICAN CONCRETE INSTITUTE
BUSINESS REPORTS

ANNUAL REPORT OF THE BOARD OF DIRECTION TO THE MEMBERS OF THE AMERICAN CONCRETE INSTITUTE, TO JANUARY 1, 1923.

The Board of Direction reports definite progress along several lines since the last convention: (1) in membership; (2) in financial condition; (3) in the activity of committees; (4) in number and variety of the papers offered at this convention; (5) in the increased demand for the published *Proceedings*, both current and back volumes.

Membership.—Membership increase has not been as much as was expected. We had 1,000 as our aim a year ago and 1,200 for the mark at this convention. We fell short in both cases.

Our increase in the last 11 months Feb. 1, 1922, to Jan. 1, 1923, was not as good proportionately as for the previous twelve months. Feb. 1, 1921, we had 542 active and 85 supporting members, total 627; Feb. 1, 1922, 722 active and 84 supporting, total, 806; Jan. 1, 1923, 849 active and 80 supporting, total, 929.

In the 11 months ending Jan. 1, 1923, we added 199 new active members and 1 new supporting member, total 200. Of this number 58 were added between Feb. 1, 1922, and the close of the last convention.

It became necessary, however, to take definite action on members delinquent for dues for more than a year, resulting in dropping 22 active members. This loss was increased by resignation of 41 active members and 5 supporting members, the loss of 7 active members by death and 2 as a result of list correction, a bookkeeping error. These represent a total loss of 72 active members and 5 supporting members, giving us net January 1, 1923, 849 active and 80 supporting members or a total of 929.

Finances.

Our balance in Bank July 1, 1921, was $4,090.81.

Our balance in Bank July 1, 1922, was $4,186.53.

For an accounting of the fiscal year ended June 30, 1922, reference is made to the report of auditors as follows:

ALBERT E. HORNE
PUBLIC ACCOUNTANT
115 Havue Ave.
DETROIT

July 23, 1922.

Mr. Harvey Whipple, Treas.
American Concrete Institute.
Detroit, Michigan.
Dear Sir:

In accordance with your instructions, we have made an examination of the books and records of the American Concrete Institute for the period from June 30, 1921, to June 30, 1922, for the purpose of verifying the Cash transactions of the period and presenting the financial condition of the Institute at that date.

We submit herewith two exhibits as follows:

Exhibit "A"—Statement of condition as of June 30, 1922.
Exhibit "B"—Statement of receipts and disbursements from June 30, 1921, to June 30, 1922.

The Cash in Bank, acounting to $4,186.53, as shown by the Cash Book, was verified by reconciliation with the statement rendered by your depository as of June 30, 1922. During our examination, paid checks all of which were properly approved, were seen for all disbursements.

The remaining items in statement of condition are shown in accordance with the records and have not been further verified by us.

We have restricted our examination to the disposition of all cash shown to have been received.

We hereby certify:

1. That all cash shown to have been received has been accounted for, and that we have seen satisfactory evidence of payment for all disbursements.

2. That the cash in bank amounting to $4,186.53, June 30, 1922, was on deposit on that date, also the Imprest Cash, amounting to $300.00 was in the hands of the Treasurer.

3. That the statement of condition (Exhibit A) is in accordance with the records and in our opinion properly presents the financial condition of the American Concrete Institute at June 30, 1922.

Respectfully submitted,

(Signed) A. E. Horne.

EXHIBIT "A"

AMERICAN CONCRETE INSTITUTE.

STATEMENT OF CONDITION.

June 30, 1922.

ASSETS.

Cash in Bank	$4,186.53	
Cash Imprest	300.00	
Total Cash		$4,486.53
Victory Bonds		3,000.00
Accounts Receivable		
Active	$1,768.56	
Contributing @ $50.00	685.00	
Contributing @ $30.00	60.00	
Special	699.98	
Delinquent—carried by request	11.86	
Miscellaneous	91.68	
		3,317.08
Inventories:		
Proceedings prior to 1916—245 @ $1.00	$245.00	
Proceedings 1917-1921—587 @ $3.75	2,201.25	
Journals 1914-1915—734 @ $0.10	73.40	
		2,519.65
Total Assets		$13,323.26

LIABILITIES.

Accounts Payable	$263.88	
Concrete Bldg. Units Fire Test Fund	155.00	
Accrued:		
Printing Proceedings est.	3,500.00	
Surplus	9,404.38	
		$13,323.26

EXHIBIT "B."

AMERICAN CONCRETE INSTITUTE.
CASH RECEIPTS AND DISBURSEMENTS.

June 30, 1921, to June 30, 1922.
As Shown by Cash Book.

RECEIPTS.

Cash—Balance June 30, 1921	$4,090.81
Cash—Dues Active	6,741.78
Cash—Dues Contributing	4,765.04
Cash Proceedings	644.24
Concrete Bldg. Units Fire Test Fund	155.00
Interest on Commercial Deposits	102.24
Interest on Victory Bonds	213.75
Miscellaneous preprint sales	101.05
Far Rockaway Fire Committee (contribution)	102.80
Total Receipts	$16,916.71

DISBURSEMENTS.

Convention	$627.03	
Miscellaneous preprints	433.95	
Office Expense	389.61	
Postage	349.67	
Pres. Office	294.59	
Printing, Stationery and News Letters	1,072.60	
Proceedings	5,269.97	
Rent	137.05	
Exchange	.48	
Salaries	3,387.33	
Traveling Exp.	223.99	
Miscellaneous Expenses	37.99	
Far Rockaway Fire Committee	202.80	
Auditor	37.50	
National Fire Protective Ass'n. membership	60.00	
Bond for Secretary-Treasurer	50.00	
Westergaard-Slater (Flat Slab)	77.81	
Moving	77.80	
Total Disbursements		$12,730.18
Balance in Bank June 30, 1922		$4,186.53

Cash receipts for the first 6 months of present fiscal year to January 1, 1923	$9,459.07
Disbursements 6 months January 1, 1923	7,452.80
We had in bank Jan. 1, 1923	9,182.80
Imprest Cash	300.00
Quick Assets	$9,482.80
Accounts Receivable	5,433.85
Inventories	3,582.50
Total Assets January 1, 1923	$18,499.15
Against total assets figure $18,499.15 we have	
A special fund collected for fire tests	$215.00
Reserve for estimated loss of delinquent members	900.00
Probable expenses to June 1, 1923	6,732.70
	$7,847.70

Lest this present too optimistic an impression, it should be explained that *Proceedings* have been paid for in the fiscal year following the year of issue. If we have early issue of *Proceedings* this year, we will be called upon to pay this bill before the end of the year by reason of earlier publication. We would then add an item of approximately $3,100 to our total, as we carried in our budget an item of only $1,900 in addition to estimate for the 1922 *Proceedings*, making a total of $10,947, nearly $11,000.

For that purpose we need to realize as promptly as possible on the $5,433.85 of Accounts Receivable. Largely delinquent dues in active and supporting membership classes.

FINANCIAL REPORT JULY 1, 1922, TO JAN. 1, 1923.

Balance in Bank, July 1, 1922 (Auditor's Report)		$4,186.53
RECEIPTS.		
Dues—Active	$4,707.05	
Contributing	3,189.98	
Proceedings Sales	768.59	
Misc. Preprint Sales	562.74	
Interest on Commercial Account and Victory Bonds	107.14	
Victory Bonds (redemption)	3,000.00	
Concrete Bldg. Units Fund	10.00	
Misc.	7.25	
Discounts (allowed on purchases)	106.32	
		12,459.07
		$16,645.60

EXPENDITURES.

Salaries	$1,864.42	
Postage	263.93	
Proceedings	3,487.69	
Printing Preprints	527.39	
Traveling Expenses	81.10	
Office Supplies	475.10	
News Letters, Membership List and Pamphlets	811.78	
Rent	189.96	
Miscellaneous	45.93	
Total of Expenditures	$7,747.30	
Less Accounts Payable Jan. 1, 1923	284.50	
		$7,452.80
Balance in Bank, January 1, 1923		$9,182.80
Balance shown by National Bank of Commerce statement 1/1/23	$9,406.67	
Outstanding Checks	223.87	
		$9,182.80

Committee Activities.

The activity of committees and the number and variety of papers are shown by this 19th convention program which includes 26 papers and 22 committee reports.

In the last year we have issued 7 *News Letters,* in January, April, June, October, November, December and January. Of the *News Letters* of December 22, we circulated 11,000 copies in addition to those sent to members.

The increased sale of our *Proceedings* indicates a livelier and wider appreciation of the record of the Institute's activities. In the 6 months of the present fiscal year, sales of extra copies of the *Proceedings* to non-members, including private and public technical libraries and others, have been nearly 50 per cent greater than the total sales for the entire previous year.

We have partially completed a detailed index of our *Proceedings* back to 1912 which we hope to publish in the next few months.

We need the help of every member in increasing membership and increasing the scope of our activities and also making effective by loyal membership boosting which we are now doing.

HARVEY WHIPPLE, *Secretary.*

Abstract of Minutes of Meetings of Board of Direction.

May 12, 1922, Cincinnati, Ohio.

Present: President Anderson, Vice-Presidents Lindau and Upson, Past-President Turner, Mr. Nichols and the Secretary.

(1) On motion duly made and approved, the Secretary was instructed in submitting existing standards to originating committees or their successors for revision in substance and conformity to the Standard Form of Standards, to submit:

The Institute Standards on Curb and Gutter Construction to the Committee on Roads and Pavements.

The Standards on Sidewalk Construction to the Committee on Floor Finish.

The Standards on Roofing Tile to a new committee on Roofing Tile which President Anderson was authorized to appoint.

The Standards on Fence Posts to a new committee on Posts, Poles, and Lighting Standards, which the President was authorized to appoint.

The Standards on Measurement of Concrete Work to a new committee on Measurement of Concrete, which the President was authorized to appoint.

(2) Discussion of the time and place of holding the next convention favored a meeting in Cincinnati, as near as possible to the middle of January, the dates suggested being Jan. 15, 16, 17 and 18, 1923; definite arrangements being left in the hands of the Secretary.

(3) The President and the Secretary were empowered to sell a sufficient number of the Institute's Victory Bonds, or use as collateral for a loan, to realize a sum not in excess of $2,000 as might be required to meet current obligations in connection with the publication of volume 18 of the Institute's *Proceedings.*

(4) The proposition of G. K. Anderson to report the Institute's next convention was accepted.

(5) The Report of the Advisory Committee, dated May 2, 1922, on committee assignments and personnel was adopted as presented with the recommendation that three subjects deserving special attention previous to the next convention are the matters of Fireproofing, referred to Committee E-4, Slag Aggregate, referred to Committee E-5, and Corrosion of Steel Reinforcing, referred to Committee E-6.

(6) There was discussion of a proposed revision in the By-Laws of the Institute, to discontinue the payment of dues upon the basis of the fiscal year and to provide for payment of dues annually in advance from the first of the month following approval of each member's application.

(7) The Secretary was authorized, in view of the earlier convention date, to notify committee-men and prospective authors that the last date for the receipt of convention material will be December 1, 1922.

SEPT. 7, 1922, NEW YORK CITY.

Present: President Anderson, Vice-Presidents Lindau and Upson, Past-Presidents Humphrey and Turner, Directors Nichols, Boyer and Pearson, and the Secretary.

(1) Ballots for the Nominating Committee were canvassed and the following committee declared elected: A. T. Goldbeck, F. R. McMillan, J. H. Chubb, H. C. Turner, K. H. Talbot.

(2) Motion was duly made and approved that the Board of Direction approve the contemplated program of tests to be carried out under the auspices of the Joint Committee of Contractors and contribute the sum of $200.00 toward the expenses of tests.

(3) The Secretary was instructed in the matter of new committees which have been authorized on the subject of Concrete Roof Tile; Posts, Poles and Lighting Standards; and Measurement of Concrete Work, to take steps to bring together at the time of the next annual convention members of the Institute and others interested in these lines of work with a view to developing out of these meetings a nucleus for each of three new committees.

(4) On motion duly made and approved the annual budget, based upon the Secretary's estimate of income and expenditure for the present fiscal year was adopted.

(5) The President and Secretary were authorized to create local committees, prior to the next Institute Convention, with a view to intensive local work in various centers of population in increasing Institute membership.

(6) In the discussion of a complaint of omitting the discussion of a patented process from the Institute *Proceedings*, it developed as the consensus of opinion of the members of the Board that a policy should be enunciated with regard to the publication of discussions of patented processes and proprietary materials.

(7) The Secretary presented a letter from the Underwriters' Laboratories, Chicago, by A. R. Small, Vice-President, under date of August 29—it being an identical letter to the American Concrete Institute, Concrete Products Association and the Portland Cement Association—on the subject of procedure in an investigation of the fire-resistance value of concrete building units, along lines substantially as reported by Committee P-5, Chairman Leslie H. Allen, to the American Concrete Institute at its 1922 convention. Approval was given to the proposed procedure covered in Mr. Small's letter.

(8) The program of the next convention was discussed at length and subjects were recommended for special emphasis as follows:

Specifications for Concrete Roads, Concrete Houses, Architectural Development in Concrete, Concrete Products.

The Secretary was instructed to make a tentative outline of a convention program for nine technical sessions and one social evening, Jan. 22-25, inclusive, 1923.

JAN. 22, 1923, CINCINNATI, OHIO.

Present: President Anderson, Vice-President Lindau, Past-Presidents Humphrey and Hatt, Directors Boyer, Nichols, Ashton, Pearson, Abrams, and the Secretary.

(1) The Secretary presented and revised a report of the Institute's condition and on motion duly made and approved this report was authorized for publication in the *Proceedings*, Vol. 19, and for presentation in digest at the convention, Tuesday, January 23.

(3) The President and Secretary were authorized to reinvest $3,000 of Institute funds, obtained by the redemption of Victory Bonds in December, in United States 4½% Treasury Certificates.

(4) The Secretary was authorized to request that Mr. A. B. Cohen, who contributed to the discussion at our 1922 convention on the subject of Plaster Bonds, submit for publication in the *Proceedings*, Vol. 19, a statement which would correct the statement of the precise methods employed in obtaining a satisfactory job of plastering on the ceiling of a New Jersey railway station, which had been mentioned in a general way in the published discussion.

In a further discussion of the policy of the Board of Direction as to the publication in the Institute's *Proceedings* of matter relating to patented processes and proprietary materials, it developed as the consensus of opinion of the Board to preclude the publication of fortuitous and impromptu discussion of proprietary materials and patented processes, expressly named, when the nature of such discussion and its off-hand presentation on the floor of the convention precluded opportunity for full consideration of other, perhaps also worthy patents and processes.

(5) The rule was adopted providing that "No paper shall be published in the *Proceedings* of the American Concrete Institute, unless such paper has been presented at the convention, and the manuscript has been available at the convention."

JAN. 25, 1923, CINCINNATI, OHIO.

Present: President Anderson, Vice-Presidents Lindau and Upson, Past-Presidents Turner and Humphrey, Directors Boyer, Nichols, Hollister, Abrams, Pearson, and the Secretary.

(1) Harvey Whipple was reappointed Secretary.

(2) The President was requested to renew the bond of the Secretary and Treasurer in the sum of $10,000 with the American Surety Company.

(3) An agreement for publishing Volume 19 of the Proceedings as entered into by correspondence between the Winston Company and the Secretary was approved.

(4) Frank C. Wight was reappointed editor of the Proceedings for Vol. 19.

(5) The Finance Committee, consisting of Messrs. Lindau, Abrams and Nichols, was reappointed.

(6) Messrs. Lindau, Boyer and Turner were reappointed to constitute, with the President and Secretary, the Executive Committee.

(7) The Advisory Committee, consisting of Messrs. S. C. Hollister, Chairman, N. M. Loney, A. T. Goldbeck, E. J. Moore, R. F. Havlik, and Harvey Whipple, Secretary, was reappointed.

(8) There was discussion of the advisability of the adoption of rules by the Board of Direction covering the presentation of papers and reports. Action was deferred pending consideration of such rules by the Advisory Committee.

(9) Acting upon the clear expression of preference by members in the convention as to the date of future conventions, as between the 21st of February and the 15th of March, a motion was made and approved fixing the date of the 1924 convention tentatively as opening Feb. 25, 1924.

Rules Governing Standing Committees.

(Adopted by Board of Direction, April 23, 1923.)

CREATION— All Institute committees are created by the action of the Board of Direction as provided in Article II, Section 5 of the By-Laws.

ORGANIZATION— Each committee shall have a chairman as designated by the Board of Direction and additional members appointed by the President (see Article II, Section 5 of the By-Laws).

Each committee shall have a secretary to be designated by the President.

MEETINGS— The meetings of standing committees shall be open only to their own members and to visitors whose proposed invitation has been approved by the chairman.

PROXIES— A member of a standing committee shall be authorized to delegate any desired individual as his proxy with or without voting power, but no individual shall have more than one vote at a meeting of a committee.

REPORTS— (1) The reports of standing committees shall be presented at the annual meeting. Reports of sub-committees shall be made to the parent committee and not to the Institute direct.

(2) The report of a standing committee, before its presentation at the annual meeting, shall first be submitted by letter ballot to all of the members of the committee and shall have received the approval of the majority of those voting. A statement of the following form signed by the Chairman or the Secretary shall appear at the close of every committee report:

> This report has been submitted to letter ballot of the committee which consists of..........members, of whom......... have voted affirmatively, ...negatively, ...have refrained from voting.

(3) Dissenting members shall have the right to present minority reports individually or jointly.

(4) All committee reports, other than proposed standards, shall be submitted complete to the secretary of the Institute three (3) weeks prior to the opening

day of the annual convention at which it is proposed to present them and notice of the nature of committee reports to be presented shall have been delivered to the Institute secretary, seven (7) weeks prior to the convention.

(5) Three weeks prior to the opening day of the annual convention, each committee chairman shall have submitted to the secretary of the Institute a report as to the personnel of his committee and the desirability of committee changes together with the proposed program of committee work for the ensuing year.

STANDARDS— The term "Standards" shall be applied collectively to (1) standard specifications, (2) standard practice, (3) standard definitions.

(1) The term "Standard Specifications" shall be applied to specifications which define the quality and characteristics of completed work.

(2) The term "Standard Practice" shall be applied to specifications designed to cover processes and construction methods.

(3) "Standard Definitions," which term is self-explanatory, comprehend the work of Committee G-4.

TENTATIVE STANDARDS— The term "Tentative Standards" shall be applied to proposed standards published in the Proceedings for one or more years with the view to eliciting criticism which the originating committee will take into consideration before recommending final action toward the adoption of Tentative Standards as Standards.

Proposed new tentative standards or proposed amendments to existing standards shall originate in the committee within whose province such subject matter belongs through the assignment of committee work by the Board of Direction.

It is further provided that any fifteen members of the Institute may, upon petition to the Board of Direction, 60 days prior to annual convention, initiate consideration on the floor of the convention of proposed amendments to existing standards.

No action affecting standards shall be taken by any committee except at meetings called for that purpose. Action shall be subject to majority vote of those voting at such meetings and subsequently to the vote of those voting on letter ballot of the entire committee. The results of each letter ballot as to the number of affirm-

ative votes, the number of negative votes and number of members not voting shall be announced by the committee to the Institute. Dissenting members shall have the right to present minority reports individually or jointly at the same annual meeting of the Institute at which the original report is presented.

ADVANCE DISTRIBUTION OF STANDARDS— Proposed new standards, proposed tentative standards, and committee amendments to and revisions of standards shall be so drawn by the originating committee as to conform to the Institute's Standard Form of Standards and shall be submitted complete to the secretary of the Institute at least seven (7) weeks prior to the opening date of the annual convention, whereupon the secretary shall cause such reports to be preprinted and mailed to the members of the Institute thirty (30) days prior to the convention as required in the By-Laws. (See Article V.)

ADOPTION OF STANDARDS— Proposed new Standards shall first be presented for adoption as Tentative Standards only. They may be amended by majority of those voting, at the convention. Upon approval by a majority vote of those voting, they shall be printed in the Proceedings as presented or as amended, as Tentative Standards on which written discussion addressed to the originating committee shall be invited.

Tentative standards as printed in the annual Proceedings and unamended except as to form may be presented for adoption as Standards at the convention next following where, upon a majority vote of those voting, they shall be referred to letter ballot to be canvassed within sixty days, by which they shall become Standards unless 10% of those voting upon such letter ballot should vote negatively. (See By-Laws, Article V.)

PATENTS— Reports, resolutions and recommended practice pertaining to and involving use or proposed use in a standard or tentative standard of a device or process which forms the subject matter of a patent, when specifically named as such, shall first be submitted to the Board of Direction and shall be submitted to the Institute only with the approval of the Board.

GENERAL COMMITTEES.

G-1: Committee on Committees.—The Committee on Committees shall be composed of the chairmen of all standing committees and members of the Advisory Committee (G-2).

The chairman and secretary of the Advisory Committee G-2 shall be the chairman and secretary, respectively, of this committee.

It shall meet once a year at the time of the annual convention.

Its duties shall be to consider the committee programs presented for the ensuing year, especially with a view to co-ordinating the technical work of the committees, avoiding duplications and for the purpose of recommending as a guide to the Advisory Committee what major subjects shall be emphasized in the year's work to make the Institute's progress of most immediate practical value.

G-2: Advisory Committee.—The Advisory Committee shall have seven (7) members to include the secretary of the Institute who shall act as secretary of the committee. The chairman shall be appointed by the Board of Direction and the five (5) other members shall be appointed by the President so as to give with the chairmen equal representation to the three major groups of Institute membership interests, namely: Engineering, Contracting and Concrete Products Manufacture.

The duties of the Advisory Committee shall be as follows:

(1) To review organization and personnel of the Institute's technical committees and make recommendations in relation thereto to the Board of Direction and to the President.

(2) To consider and recommend to the Board of Direction, the acceptance or rejection of reports proposed for presentation at each succeeding convention with a view to limiting the consideration of some subjects and increasing the consideration of others in making the best possible convention program.

(3) To act as an aid to the Board of Direction in the preliminary details of conventions and in issuing the annual Proceedings.

(4) To consider the program of each technical committee and recommend definite committee assignments to be made by the Board of Direction.

G-3: Committee on Form of Standards.—The duties of the Committee on Form of Standards shall be to review and to pass upon in an editorial capacity, with respect to the Institute's Standard Form of Standards, all standards proposed for adoption by the Institute.

G-4: Nomenclature.—It shall be the duty of the committee on Nomenclature to study and effect standardization so far as possible in the acceptance of terms and definitions peculiar to or having special relation to the field of concrete design, construction and manufacture.

MEMBERS AMERICAN CONCRETE INSTITUTE.

Active Membership .... $10.00 per year
Supporting Membership .... $50.00 per year

An Asterisk (*) designates a Supporting Member

Members will please send to the Secretary a correction of any error of name or address in this list.

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American Sanitary Products Co., Stamford, Conn. (F. M. Brown, Pres.)

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Arnold Stone, Brick & Tile Co., Inc., Lem Turner and 47th Sts., Jacksonville, Fla. (M. A. Arnold.)

Asbestos Shingle, Slate & Sheathing Co., Ambler, Pa. (Richard V. Mattison.)

Asher Fire Proof Co., 915 Southern Bldg., Washington, D. C. (C. B. Asher, Pres.)

Ash Grove Lime & Portland Cement Co., Box 1132, Kansas City, Mo. (A. Lundteigan.)

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Associated Portland Cement Mfrs., Ltd., Park House, Gravesend, England. (H. R. Cox.)

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Badger Concrete Co., 191 Marion St., Oshkosh, Wis. (E. Olsen.)

Baer Engineering & Construction Co., Box 74, Leavenworth, Kan. (B. E. Baer.)

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BILLINGHAM & COBB, 404 Press Bldg., Kalamazoo, Mich. (L. A. Cobb.)
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BUFFALO WASH TRAY WORKS, 601 Tonawanda St., Buffalo, N. Y. (M. J. Deutch.)
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CARNEGIE LAND CO., 357 Frick Annex, Pittsburgh, Pa. (Roger H. McGee.)
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CEMENT-GUN CO., INC., Allentown, Pa.
CEMENT GUN CONST. CO., 537 S. Dearborn St., Chicago, Ill. (J. V. Schaefer, Pres.)
CEMENT PRODUCTS CO., P. O. Box 935, Birmingham, Ala. (G. L. Cox, Pres.)

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CINCINNATI BUILDERS SUPPLY CO., 534 Main St., Cincinnati, Ohio. (F. H. Kinney.)

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*CLINCHFIELD PORTLAND CEMENT CORPORATION, Kingsport, Tenn.

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*INSLEY MFG. CO., P. O. Box 167, Indianapolis, Ind. (Wm. H. Insley.)

*INSLEY MFG. CO., P. O. Box 167, Indianapolis, Ind. (Alvin C. Rasmussen.)

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JOHNSTON, ROBERT S., 3604 McKinley St., Washington, D. C. (Bureau of Standards.)

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*KALMAN CO., PAUL J., 22 W. Monroe St., Chicago, Ill. (G. E. Routh.)

*KALMAN CO., PAUL J., 22 W. Monroe St., Chicago, Ill. (W. E. White.)

KALMAN FLOOR CO., THE, 22 W. Monroe St., Chicago, Ill. (C. E. Cooke.)

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*KEARNS CONSTR. CO., 153 Milk St., Boston, Mass. (W. F. Kearns.)
KELLEY, FREDERICK W., 126 State St., Albany, N. Y. (Hildenberg Cement Co.)
KELTY, EMER G., 122 N. 51st St., Philadelphia, Pa. (Consolidated Expanded Metal Co.)
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*KNICKERBOCKER PORTLAND CEMENT CO., 342 Madison Ave., New York City. (Th. Avnsoe.)
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KNUDSEN, AX. M. AND S. L. SORENSEN, Vesterbrogade 13, Copenhagen, Denmark. (N. J. Nielsen.)
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*KOEHRING COMPANY, 31st and Concordia Ave., Milwaukee, Wis. (P. Koehring.)
*KOEHRING COMPANY, 4940 N. 8th St., Philadelphia, Pa. (George A. Sherron.)
KOERNER & CO., C. A., 318 E. Burnett, Louisville, Ky. (R. J. Sweeney.)
KOMURO, MANGORO (IWAKI CEMENT & CO., LTD.), Yotsu Kuracho, Fukushi, Maken, Japan.
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*KOSMOS PORTLAND CEMENT CO., 614 Paul Revere Bldg., Louisville, Ky. (O. N. Clarke.)
KRAUSE-JUDSON CO., Juneau, Alaska. (G. E. Krause.)
KRAUSE, MARK C., 120 West 4th St., Williamsport, Pa.
KRECKER, RAYMOND H., c. o. Phila. & Reading Ry., 9th & Spring Garden Sts., Philadelphia, Pa.
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LAGAARD, M. B., Experimental Engineering Bldg., Minneapolis, Minn. (University of Minnesota.)
LAKE, SIMON, Milford, Conn.

Lamb Co., Robert E., 843 North 19th St., Philadelphia, Pa. (Robert E. Lamb.)

Lambert, Walter E., 2028 Lincoln St., Evanston, Ill.

Lambie, J. Edward, 5901-5999 Hydraulic Ave., Cleveland, O. (Lambie Concrete House Corp.)

Lambie, Joseph S., Parkman Blvd., Pittsburgh, Pa. (University of Pittsburgh.)

Lander, R. S., Burwell Bldg., Knoxville, Tenn. (Sherman Concrete Pipe Co.)

Landor, Edward J., 634 Renekert Bldg., Canton, Ohio.

Lane, H. A., Baltimore and Ohio Central Bldg., Baltimore, Md. (Baltimore & Ohio Railroad Co.)

Lapham, John R., 1829 G St., N. W., Washington, D. C. (George Washington Univ.)

"La Tolteca," Cia de Cemento, Portland, S. A., Independencia 8, P. O. Box 233, Mexico, D. F. Mexico. (G. H. E. Vivian.)

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*Lawrence Portland Cement Co., Northampton, Pa. (J. S. Van Middlesworth, 302 Broadway, New York City.)

Lea, William S., 809 New Birks Bldg., Phillips Square, Montreal, Que. (R. S. & W. S. Lea.)

Leffler, Ralph R., 7021 Oriole Ave., Chicago, Ill.

Lehigh Portland Cement Co., Young Bldg., Allentown, Pa.

*Leonard Construction Co., 375 Wabash Ave., Chicago, Ill. (Clifford M. Leonard.)

Leonard, John B., 57 Post St., San Francisco, Cal.

Lesley, Robert W., 611 Pennsylvania Bldg., Philadelphia, Pa.

*Levering & Garrigues Co., 552 West 23rd St., New York City. (C. B. Wigton.)

*Ley & Co., Inc., Fred T., 495 Main St., Springfield, Mass. (Raymond K. Turner.)

Libberton, J. H., 40 Rector St., New York City. (General Chemical Co.)

Lieberman & Hein, 190 N. State St., Chicago, Ill. (C. Lieberman.)

Lilley Concrete Products Co., Aurora, Ill. (L. W. Lilley.)

Lind, Peter & Co., 2 Central Bldg., Westminster, London, S. W. 1, England.

Lindau, A. E., Corrugated Bar Co., Buffalo, N. Y.

Lindsay & Co., W. W., 902 Harrison Bldg., Philadelphia, Pa. (James C. Newlin, V. P.)

Lindsley Co., C. E., 888 Clinton Ave., Irvington, N. J. (C. E. Lindsley.)

Litter, F. J., 8 W. 40th St., N. Y. C. (The Frederick Snare Corp.)

Livermore, A. C., Mgr. Westinghouse Air Brake Home Bldg. Co., Wilmerding, Pa.

Lock Joint Pipe Co., P. O. Box 21, Ampere, N. J. (A. M. Hirsh.)

Locke, Clyde E., 905 Ellicott Sq., Buffalo, N. Y. (A. E. Baxter Eng. Co.)

LOCKHARDT, BYRNE CO., INC., 512 Fifth Ave., New York City, N. Y. (William F. Lockhardt.)

LOCKWOOD, GREENE & CO., 24 Federal St., Boston, Mass. (Library.)

LOGEMAN, R. T., 208 S. LaSalle St., Chicago, Ill. (American Bridge Co.)

LONEY, NEIL M., 51 Wall St., New York City. (Thompson-Starrett Co.)

LORD, ARTHUR R., 140 S. Dearborn St., Chicago, Ill. (Lord Eng. Co.)

LOS ANGELES CONCRETE TILE CO., 432 I. W. Hellman Bldg., Los Angeles, Cal. (Harry Soderberg.)

LOTHIAN, ALBERT J., 230 Chatham St., W., Windsor, Ont., Can.

LOVE, GEORGE C., Newport News, Va. (Old Dominion Land Co.)

LOVE, HARRY J., 933 Leader-News Bldg., Cleveland, Ohio. (Nat. Slag Assn.)

LOWELL, JOHN W., 208 LaSalle St., Chicago, Ill. (Universal Portland Cement Co.)

LOWRY, JR., JOHN, 171 Madison Ave., New York, N. Y.

LUNDOFF-BICKNELL CO., THE, 5716 Euclid Ave., Cleveland, O. (C. W. Lundoff.)

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MCCLELLAN & JUNKERSFELD, 45 William St., New York City. (H. T. Campion.)

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MCINTYRE MACHY. CO., 708 Empire Bldg., Detroit, Mich. (A. E. Carpenter, Secy.)

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MCRAE STEEL CO., 16 McGraw Bldg., Detroit, Mich. (William Corman.)

MACATEE, W. L., & SONS, Austin and Commerce Sts., Houston, Tex.

MACONI, G. V., 67 Church St., New Haven, Conn. (The Dwight Building Co.)

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MALONEY, ROWLAND, 19 Trunk Rd., Pallavaram, India (Ideal Tile and Cement Works.)

MALONE, JOHN A., Lancaster, Pa. (Malone & Sons.)
MANITOBA, UNIVERSITY OF, Sherbrooke and Portage Sts., Winnipeg, Man. (J. N. Finlayson.)
MANTICA, ALBERT J., 607 Dickinson Bldg., Norfolk, Va. (Truscon Steel Co.)
MARBLE, WILLIAM O., 508 London Bldg., Vancouver, B. C. (Hodgson, King & Marble.)
M. B. MARKLAND, Guarantee Trust Bldg., Atlantic City, N. J.
MARLBORO CEMENT CO., Edmonton, Alberta, Can. (A. W. G. Clark.)
MARQUETTE CEMENT MFG. CO., Marquette Bldg., Chicago, Ill. (T. G. Dickinson.)
MARSHALL, JOHN, 528 Collins St., Melbourne, Victoria, Australia. (The Marshall Concrete Co., Ltd.)
MARSCH-MURDOCK CO., THE, Melish & Stanton Aves., Cincinnati, O. (George J. Marsch.)
MARTIN, EVAN S., 16 Saulter St., Toronto, Ont. (James A. Wickett, Ltd.)
MASSEY CONCRETE PRODUCTS CORP., Peoples Gas Bldg., Chicago, Ill. (Paul Kircher.)
MASTER BUILDERS CO., THE, 1836 Euclid Ave., Cleveland, Ohio. (S. W. Flesheim.)
MASTRANGELO, M. J., 369 Hanover St., Boston, Mass.
MAYNARD, ARTHUR J., Mass. State Farm, State Farm, Mass.
MAYNICKE & FRANKE, 25 Madison Sq. North, New York City, N. Y. (Julius Franke.)
MAZUR, ISADOR, 3610 Balsam Ave., Indianapolis, Ind.
MEAD, C. A., 165 Wildwood Ave., Upper Montclair, N. J.
MEAD, SUYDAM CO., 342 6th Ave., Newark, N. J. (F. J. Mead, Pres.)
MEADERS, ERNEST LAMAR, McComb, Miss. (E. L. Meaders Co.)
MERCHANT, ARCHIE W., 728 Hospital Trust Bldg., Providence, R. I. (William & Merchant, Inc.)
MESSEY, LAUREL, Commerce Bldg., Ash and George Sts., Sydney, Australia.
METCALF & EDDY, 14 Beacon St., Boston, Mass. (Frank A. Marston.)
MEYER, C. LOUIS, 608 Omaha National Bank Bldg., Omaha, Neb. (Concrete Engrg. Co.)
MEYER, MORRISON & CO., 39 Cortlandt St., New York City.
MICHIGAN PORTLAND CEMENT CO., Chelsea, Mich. (G. S. Potter, Jr.)
MICHIGAN UNIVERSITY LIBRARY, Ann Arbor, Mich.
MIESENHELDER, P. D., 317 E. 12th St., Indianapolis, Ind. (Ind. State Highway Comm.)
MILLER, CHARLES R., CO., INC., 556 Susette St., Memphis, Tenn.
MINER, JOSHUA L., 814 Second Pl., Plainfield, N. J.
MITCHELL, JAMES, 76 Montgomery St., Jersey City, N. J.
MITCHELL, NOLAN D., 220 Beach Et. South, Clarendon, Va. (U. S. Bureau of Standards.)
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Mohler, John D., Court House, St. Joseph, Mo. (Highway Engineer, Buchanan County.)

Mollenkof, J. P., c. o. John H. McClatchy, Erdenheim, Pa.

Monks & Johnson, 99 Chauncey St., Boston, Mass. (John R. Nichols.)

Monolithic Hollow Concrete Form Corp., 326-330 Pacific Finance Bldg., Los Angeles, Cal. (L. J. Desenberg.)

Moore, Thomas, The Adensite Co., 116 W. 39th St., N. Y. C.

Moores-Coney Co., 111 East Fourth St., Cincinnati, O. (W. W. Coney.)

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Moyer, Albert, 350 Madison Ave., New York. (Vulcanite Portland Cement Co.)

Mueller, Harold P., 4738 N. Canal St., Logan, Philadelphia, Pa.

Mueller, J. W., Palladium Bldg., Richmond, Ind.

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National Fireproofing Co., Flatiron Bldg., New York City. (P. Bevier.)

National Lime Association, 918 G. St., N. W., Washington, D. C.

National Stone Tile Corp., 625 Market St., San Francisco, Calif. (C. C. H. Thomas.)

*Nassau Sand & Gravel Co., 949 Broadway, New York City. (W. J. Timberman.)

Nasu, Akiya, Kawasaki Works, Nakashibuya, No. 715, Tokyo, Japan.

*Nazareth Portland Cement Co., Nazareth, Pa. (J. A. Horner.)

Nelson, John A., 1800 Eleventh St., Rock Island, Ill. (Cut Stone Co.)

Neuffer, George T., 509 W. Second St., Dayton, Ohio.

*Newaygo Portland Cement Co., Newaygo, Mich. (J. D. John.)

New Jersey Zinc Co., Palmerton, Pa. (Works Library.)

Nichols, Charles Eliot, 147 Milk St., Boston, Mass. (Stone & Webster, Inc.)

Nicholson, Jr., John, 2735 Prospect Ave., Cleveland, Ohio.

Noble & Co., R. E., 624 Sacramento St., San Francisco, Cal. (Theodore P. Dresser, Jr.)

Noice, Blaine, 1326 Washington Bldg., Los Angeles, Cal.

Noonan, W. H., Metropole Bldg., Halifax, Nova Scotia.

Northwestern States Portland Cement Co., Mason City, Ia. (W. Cowhan.)

Norton, Edgar W., 390 Main St., Worcester, Mass.

Novella, Gustavo, Avenida del Hipodromo, Guatemala, Guatemala, C. A.

Oakey, Charles W., Madison, Wis. (Bridge Dept., Wis. Highway Comm.)

Oehmann, John W., Room 110, District Bldg., Washington, D. C. (Prin. Asst. Inspector of Buildings, D. C.)

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Ogden Portland Cement Co., Room 521, Eccles Bldg., Ogden, Utah. (R. C. Briscoe.)

Okubo, Toshiyuki (Truscon Steel Co. of Japan), Yurakucho Kojimachi, Tokyo, Japan.

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Ord, William, 210 North Clinton St., Chicago, Ill.

Orr, John B., 6th St., Miami, Fla.

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Oscar, L. C., Bureau of Standards, Washington, D. C.

*Ottawa Silica Co., Ottawa, Ill. (C. B. Herring.)

Overpeck, O. E., Swift & Co., Chicago, Ill.

Paget, A. Maxwell, 224 N. Front St., Wormleysburg, Pa.

Painter, W. S., Engineers Club, New York City, N. Y.

Parker, Frank S., 280 Madison Ave., New York City. (Parker & Shaffer.)

Parry, Charles, 510 Pennsylvania Bldg., Philadelphia, Pa. (Chf. Engr. Direct Oxidation Disposal Co.)

Pattillo, James N., 1716 W. 42nd St., Los Angeles, Cal.

Peabody, Dean, Jr., Room 301, Mass. Institute of Technology, Cambridge, Mass.

Pearse, Langdon, 910 S. Michigan Ave., Chicago, Ill. (Sanitary District of Chicago.)

Pearson, J. C., Bureau of Standards, Washington, D. C.

Pease, B. S., 208 S. LaSalle St., Chicago, Ill. (Am. Steel & Wire Co.)

*Peerless Portland Cement Co., Union City, Mich. (William M. Hatch.)

*Penn-Allen Portland Cement Co., Widener Bldg., Allentown, Pa. (W. E. Eidel.)

*Pennsylvania Cement Co., 30 E. 42nd St., New York City. (Wm. Beach.)

Pennsylvania State Highway Dept., Harrisburg, Pa. (W. H. Connell, Asst. State Highway Comm.)

Perrot, Emile G., Boyertown Bldg., 1211 Arch St., Philadelphia, Pa.

Perrott, Leslie M., Architect, 243 Collins St., Melbourne, Victoria, Australia.

PIERSON CONCRETE PRODUCTS CO., 89 Dodd St., East Orange, N. J. (M. De Forrest Soverel.)

PITTSBURGH TESTING LABORATORY, 7th and Bedford Ave., Pittsburgh, Pa. (P. J. Freeman.)

PLAGWIT, ERIC, 123 W. Madison St., Chicago, Ill.

PLANO CONCRETE WORKS, Box B, Plano, Ill. (Chas. A. Steward.)

PLUMER, H. E., 22 Ellicott Square, Buffalo, N. Y.

THE POLLAK STEEL CO., P. O. Box 461, Cincinnati, O. (Julian A. Pollak, V. P.)

PORTER, J. M., Easton, Pa.

*PORTLAND CEMENT ASSN., 111 W. Washington St., Chicago, Ill.

POST & MCCORD, 101 Park Ave., New York, N. Y. (Andrew J. Post, Pres.)

POST MFG. CO., c|o Kent Machine Co., Kent, Ohio. (F. R. Brantigam.)

POWERS & SON, EUGENE S., 315 S. 15th St., Philadelphia, Pa. (E. S. Powers.)

PRACK, BERNARD H., 50 Bay St., Toronto, Ont. (Prack & Perrin.)

PRATT, H. B., Antrim, N. H.

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PUCCI, ANGELO, 325 Central Park, Rochester, N. Y.

PURVES, JOHN, 914 Monadnock Block, Chicago, Ill. (Wells Bros. Const. Co.)

QUEBEC DEPT. OF PUBLIC WORKS & LABOR, Government Bldgs., Quebec, P. Q. (Ivan E. Vallee.)

QUEBEC DEPT. OF ROADS, Parliament Bldgs., Quebec, P. Q. (B. Michaud.)

RADER, B. H., Conway Bldg., Chicago, Ill. (Lehigh Portland Cement Co.)

RADIGAN, FRANK J., Court House, Jersey City, N. J.

RANDALL, FRANK A., 19 S. LaSalle St., Chicago, Ill. (Berlin, Swerm & Randall.)

RANSOHOFF, V., Ideal Concrete Machinery Co., Cincinnati, Ohio.

*RANSOME CONCRETE MACHINERY CO., Dunellen, N. J. (A. P. Robinson.)

*RANSOME CONCRETE MACHINERY CO., Dunellen, N. J. (A. P. Robinson.)

*RAYMOND CONCRETE PILE CO., 140 Cedar St., New York City. (H. P. Hamlin.)

REED CO., WILLIAM T., 200 Devonshire St., Boston, Mass. (William T. Reed.)

REUBELL, J. C., 1000 W. Washington Ave., N. Little Rock, Ark. (Mar granite Products Co.)

REYNVAAN, A. J., 2036 Wendover, Pittsburgh, Pa.

RHEINSTEIN & HASS, INC., 21 E. 40th St., New York City. (A. Rheinstein.)

RHETT, ALBERT H., Room 709, 320 Fifth Ave., New York City. (Toch Bros.)

RIB-STONE CONCRETE CORP., 2-3 Chamber of Commerce Bldg., Batavia, N. Y. (George E. Priest.)

RICE, JAMES, P. O. Box 10, Forest Hills, L. I.

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Richardson-Jones, Harry, 357 Beach Walk, Honolulu, Hawaii.

Richart, Frank E., University of Illinois, 300 Lab. of Applied Mechanics, Urbana, Ill.

Richmond, Knight C., 10 Weybossett St., Providence, R. I.

Riesche, Robert H., 306 Trimble Blk., Sioux City, Ia. (Riesche & Sanborn.)

Ritter, Louis E., 140 So. Dearborn St., Chicago, Ill. (Ritter & Matt.)

Robinson, Albert Fowler, Room 1033, Railway Exchange Bldg., Chicago, Ill. (A., T. & S. F. R. R. System.)

Robinson, C. C., 1004-5 Times-Despatch Bldg., Richmond, Va. (Chas. M. Robinson.)

Robinson & Co., Inc., Dwight P., 125 E. 46th St., New York City. (M. E. Thomas.)

Rockefeller, Lloyd H., Poplar St. & Jefferson Ave., Queens, L. I., N. Y. (Cemprod Engrg. & Constr. Co.)

Rodgers, W. C., Engineer in Chief, Delhi (New Capital) Ry. Works Scheme, P. O. Raisina, Delhi, India.

Rogers, Floyd, Newton, Iowa.

Rollins, James W., 6 Beacon St., Boston, Mass. (Holbrook, Cabot & Rollins.)

Rollins, J. Frank, 802 Owen Bldg., Detroit, Mich. (Michigan Architect & Engineer.)

Roos Co., The H. W., 2036-46 Dana Ave., Cincinnati, Ohio. (H. W. Roos.)

Royal Swedish Board of Waterfalls, Regeringsgatan 45, Stockholm, 3, Sweden. (Axel Ekwall.)

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*Sandusky Cement Co., 626 Engineers Bldg., Cleveland, O. (Wm. B. Newberry.)

Santa Cruz Portland Cement Co., Davenport, Cal. (Llewellyn T. Bachman.)

Saum, Irving R., 3218 Newark St., N. W., Washington, D. C. (Chas. H. Tompkins.)

Saunders, W. L., 1323 Columbia Road, Washington, D. C. (Concrete Steel Co.)

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SAVILLE, CHRISTOPHER JAMES, Portland, New South Wales, Australia. (Commonwealth Portland Cement Co.)
SCHAEFER BROS., 121 Powers Bldg., Rochester, N. Y. (Albert F. Schaefer.)
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SCHOULER CEMENT CONSTRUCTION CO., 154-6 Frelinghuysen Ave., Newark, N. J. (D. D. Schouler.)
SCHUSTER, K. R., 15 Park Row, New York, N. Y.
SCHWALBE, WILLIAM, 711 W. Springfield St., Urbana, Ill. (University of Illinois.)
SCOFIELD ENGR. CONSTRUCTION CO., Wright-Callender Bldg., Los Angeles, Cal. (C. M. Scofield.)
SCOTT, J. R., Ross & Scott, Welland, Ont., Can.
SECURITY CEMENT & LIME CO., Hagerstown, Md. (John Porter.)
SEELYE, ELWYN E., 101 Park Ave., New York City.
SEWELL, JOHN S., c/o Alabama Marble Co., Birmingham, Ala.
SEXTON, F. H., N. S. Technical College, Halifax, N. S.
SHAFFER, IVAN O., 280 Madison Ave., N. Y. C. (Parker & Shaffer.)
SHANK, J. R., 97 W. Tompkins St., Columbus, Ohio.
SHATTUCK, INC., L. H., 208 Granite St., Manchester, N. H. (George G. Shedd.)
*SHEARMAN, A. N., 1006 Burwell Bldg., Knoxville, Tenn.
SHELDON, F. P., & SON, Hospital Trust Bldg., Providence, R. I.
*SHENK CO., HENRY, Erie, Pa. (E. R. Shenk.)
SHERMAN, RALPH A., Quarry and Taylor Place, Trenton, N. J. (State Highway Comm. Laboratory.)
SHERRON, GEO. A., 4835 N. 8th St., Philadelphia, Pa.
SHERTZER, TYRILL B., 100 Hamilton Place, New York, N. Y. (National Lime Association.)
SHIBAURA ENGINEERING WORKS, LTD., 1 Shinhamacho, Kanasugi, Shiba—Ku, Tokyo, Japan. (M. Sekiguchi.)
SHOPE BRICK CO., 361½ E. Morrison St., Portland, Ore. (D. F. Shope.)
SIESEL, S. M., 105 Wells St., Milwaukee, Wis.
SIMPSON, GEORGE, 51 Wall St., New York City. (Thompson-Starrett Co.)
SIMPSON, LOUIS, 172 O'Connor St., Ottawa, Ont.
SIMPSON BROS. CORP., 166 Devonshire St., Boston, Mass. (J. P. Simpson.)
SKAY, A. J., 3925 Nebraska Ave., St. Louis, Mo.
SIOCHI, PEDRO, Salazar 407, Manila, P. I.
SLATER, WILLIS A., Bureau of Standards, Washington, D. C.
SMITH, BLAINE S., 210 S. LaSalle St., Chicago, Ill. (Universal Portland Cement Co.)
SMITH, GEORGE A., Bureau of Standards, Washington, D. C.
SMITH, MAJOR N. H., Imber Court, East Molesey, Surrey, England.
SMOLEY, CONSTANTINE K. (International Text Book Co.), Scranton, Pa.

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Snider, J. C., Camden, Ohio.

Snodgrass, R. D., 29 Broadway, New York City. (Hamilton & Chambers.)

Snyder, J. N., Arapahoe, Neb.

Societe Des Ciments Francais, 80 Rue Taitbout, Paris, France. (F. Turquais.)

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Southern California Edison Co., Edison Bldg., Los Angeles, Cal.

Southern Concrete Products Co., Box 97, Anderson, S. C. (W. Carl Austin, Secy. and Treas.)

Southwestern Portland Cement Co., 610-11 Mills Bldg., El Paso, Tex. (H. C. Swearingen.)

Spaulding, Ralph E., Apartado 1529, Lima, Peru. (Fred T. Levy & Co., Inc.)

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Spiker & Lose, 519-20 Forsyth Bldg., Atlanta, Ga. (William C. Spiker.)

Spinosa, Arthur V., Braddock, Pa. (Consolidated Exp. Metal Co.)

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Standard Oil of New Jersey, P. O. Box 37, Elizabeth, N. J. (Charles E. Haupt.)

Standard Slag Co., Youngstown, Ohio. (F. E. Miller.)

State Mfg. Co., Inc., 22nd St. and Debree Ave., Norfolk, Va. (J. F. W. Fawcett, Pres.)

Steele & Sons Co., Wm., 1600 Arch St., Philadelphia, Pa. (Edward A. Steele.)

*Steele & Sons Co., Wm., 1600 Arch St., Philadelphia, Pa. (Edward A. Steele.)

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Storr, Albert E., 306 Chestnut St., Westfield, N. J.

Stout, The Marion F., Co., 34th and Decoursey, Covington, Ky. (Marion F. Stout.)

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STURDEVANT, H. H., 622 Cudahy Ave., Cudahy, Wis.
SUPERIOR PORTLAND CEMENT CO., Concrete, Wash. (C. L. Wagner.)
SUTER, OSCAR M., c/o Vaccaro Bros. Co., La Ceiba, Spanish Honduras, Central America.
SUTHERLAND, HALE, Mass. Institute of Technology, Cambridge, Mass.
SWAIN, GEORGE F., Harvard University, Cambridge, Mass.
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TALBOT, KENNETH H. (Koehring Machine Co.), Milwaukee, Wis.
TAMMINGA, WM., 1620 S. Washington St., Denver, Colo.
TECHNISCHE HOOGESCHOOL, Onde Delft 69, Delft, Holland. (J. A. Bakker.)
TEKNISK BIBLIOTEK, Copenhagen K., Denmark. (Helge Holst.)
TELLYER, HARRY B., 2810 N St., San Diego, Cal. (Cal. Glazed Cement Pipe Co.)
TEXAS PORTLAND CEMENT CO., Dallas, Tex. (H. C. Koch.)
THAYER, L. V., 25 W. 43rd St., Suite 908, New York City.
THOMAS, A. O., 8540 Dexter Blvd., Detroit, Mich.
THOMPSON, E. G., Pine Alley, New Kensington, Pa.
*THOMPSON & BINGER, 280 Madison Ave., New York City.
THOMPSON-LICHTNER CO., 136 Federal St., Boston, Mass. (Sanford E. Thompson.)
*THOMPSON-STARRETT CO., 51 Wall St., New York City. (N. M. Loney.)
THOMPSON, WILLIAM G., Bay Construction Co., St. Petersburg, Fla.
THURTLE, JOHN G., 3304 Flora Ave., Kansas City, Mo.
TIDEWATER PORTLAND CEMENT CO., Union Bridge, Md. (G. S. La Forge.)
TINKHAM CEMENT PRODUCTS WORKS, Palmetto, Fla. (M. E. Tinkham.)
TINKLER, J. W., 315 Snowden Ave., Bedford Pk., Toronto, Ont.
TOCH BROS., 320 Fifth Ave., New York City. (Maximilian Toch.)
TOMPKINS, CHARLES H., 1612 Park Road, N. W., Washington, D. C.
TORREY, JAMES E., 652 E. 26th St., Paterson, N. J. (John W. Ferguson Co.)
TOZZER, A. C., 178 Tremont St., Boston, Mass. (Turner Construction Co.)
TRAYLOR-DEWEY CONTRACTING CO., Allentown, Pa. (Willis Leriche.)
TRUFANT, RUSSELL ALDEN, 209 West Elm St., Carbondale, Ill. (Division of Highways.)
TRUMBULL, MARK M., c/o State Highway Commission, Raleigh, N. C.
*TRUSCON STEEL CO., Owen Bldg., Detroit, Mich. (S. Fechheimer.)
*TRUSCON STEEL CO., Youngstown, Ohio. (H. N. Sturdy.)
*TRUSCON STEEL CO., Youngstown, Ohio. (T. H. Kane.)

Tubesing, William F., Wauwatosa, Wis.
Turner, C. A. P., 627 First Ave. N., Minneapolis, Minn.
Turner, John J., & Sons, Amsterdam, N. Y.
*Turner Construction Co., 244 Madison Ave., New York City. (H. C. Turner.)
*Turner Construction Co., 244 Madison Ave., New York City. (E. J. Moore.)
*Turner Construction Co., 244 Madison Ave., New York City. (R. C. Wilson.)
*Turner Construction Co., 244 Madison Ave., New York City. (T. A. Smith.)
Twogood, L. Scott, 1166 Rookery Bldg., Chicago, Ill.
Underwriters' Laboratories, 207 E. Ohio St., Chicago, Ill. (A. R. Small.)
Unit Construction Co., 1225 Title Guaranty Bldg., St. Louis, Mo. (C. C. Smith.)
United States Cement Tile Co., 2223 Farmers Bank Bldg., Pittsburgh, Pa. (R. L. Martin.)
United States Portland Cement Co., 305 Ideal Bldg., Denver, Colo. (Fred A. Schmidt.)
Universal Concrete Products Co., New Martinsville, W. Va. (H. Eschenbrenner.)
*Universal Portland Cement Co., 210 S. LaSalle St., Chicago, Ill.
Upham, Charles M., c/o State Highway Comm., Raleigh, N. C.
Upson, Maxwell M., 140 Cedar St., New York City. (Raymond Concrete Pipe Co.)
Vandever, Jacob B., 1270 Broadway, New York City. (Nazareth Cement Co.)
Van Doorn, J. C., 836 Security Bank Bldg., Minneapolis, Minn. (Universal Portland Cement Co.)
Van Dyke, C. W., Asst. Gen. Mgr. Hampton Paint & Chemical Co., Springfield, Mass.
Van Scoyoc, H. S., Montreal, Que. (Canada Cement Co., Ltd.)
Van Tasel, G. W., Weeks Ave., Houlton, Me.
Verkouteren, A. J., 118 S. 22nd St., Philadelphia, Pa.
Vigorose Cement Industrie, N. V., de Steeg, Holland. (B. A. Honig.)
Villadsen, James M., 303 Dooly Bldg., Salt Lake City, Utah. (Villadsen Bros., Inc.)
Villadsen, A. B., 303 Dooly Bldg., Salt Lake City, Utah. (Villadsen Bros., Inc.)
Vogel, John Leonard, 9 Hillside Ave., Box 336, Chatham, N. J. (New Jersey State Highway Commission.)
Voorhees, S. F., 342 Madison Ave., Room 2022, New York City.
Vortex Mfg. Co., 1978 W. 77th St., Cleveland, Ohio. (Chas. H. Parkin.)
Voshell, James T. (U. S. Bureau of Public Roads), Post Office Bldg., South Chicago, Station S, Chicago, Ill.

VOSS, WALTER C., Wentworth Institute, Boston, Mass.

VULCANITE PORTLAND CEMENT CO., 350 Madison Ave., New York City. (Albert Moyer.)

WADA, TOYOJI, Mukojima Suzokicho, Tokyo, Japan.

WADDELL, WILLIAM H., P. O. Box 364, Niagara on the Lake, Ontario.

WAIT, B. H., 347 Madison Ave., New York City.

WALKER, STANTON, 1951 W. Madison St., Chicago, Ill. (Structural Materials Research Laboratories.)

WALLACE, W. K., Midland Ry., York Rd., Belfast, Ireland.

WALTER, ERNEST, 263 Midland Ave., Montclair, N. J. (Porete Mfg. Co.)

WARD, HARRY A., 11 Goodell St., Buffalo, N. Y. (Turner Const. Co.)

WARNER CO., CHAS., Finance Bldg., Philadelphia, Pa. (F. S. Lee.)

WARREN CO., F. V., 132 S. 17th St., Philadelphia, Pa. (F. V. Warren.)

WARREN, GEORGE E., 111 N. Washington St., Chicago, Ill. (Portland Cement Ass'n.)

WASSIF, K. ZAKI, Bureau des Ponts et Chaussees, Amiens (Somme) France.

WASHBURN, CHARLES E., 410 Union Nat'l Bank Bldg., Houston, Tex.

WATERLOO CONSTRUCTION MACHINERY CORP., Waterloo, Iowa. (G. D. Arthur.)

WATSON ENGINEERING CO., 4614 Prospect Ave., Cleveland, Ohio. (W. J. Watson.)

WAY, W. F., Bremerton, Wash. (Henry & McFee.)

WEARY & ALFORD CO., 1923 Calumet St., Chicago, Ill. (Gardner C. Coughlen.)

WEBB, JR., T. S., 1200 Island Home Pike, Knoxville, Tenn. (New Cast Stone & Tile Co.)

WEINBERGER, A. J., Beach, N. D.

WEIR, C. LESLIE, 41 E. 42nd St., New York, N. Y. (American Ice Co.)

WEISS, PHILIP, 132 E. 7th St., Philadelphia, Pa.

WEITZ, FRED W., 713-15 Mulberry St., Des Moines, Ia. (Charles Weitz's Sons.)

WELLS, HEWITT, Woodward Bldg., Washington, D. C.

WELLS, P. A., 914 Monadnock Block, Chicago, Ill. (Wells Bros. Const. Co.)

WEMYSS, F. D., c/o A. S. Hall & Co., Taiping, Federated Malay States.

WENDELN, D. F., 542 Milton St., Cincinnati, Ohio.

WENZEL, JR., HERMAN, 201 S. Culver St., Chippewa Falls, Wis. (Chippewa Cement Block Works.)

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WESTINGHOUSE ELECTRIC MFG. CO., E. Pittsburgh, Pa. (J. E. Webster.)

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WHEELER, WALTER H., 1112 Metropolitan Life Bldg., Minneapolis, Minn.

White & Co., Barclay, 1713 Sansom St., Philadelphia, Pa. (Barclay White.)

*White Construction Co., Inc., 95 Madison Ave., New York City. (G. Edward Escher.)

*Whitehall Cement Mfg. Co., 1736 Land Title Bldg., Philadelphia, Pa. (H. Greene.)

Whitney Bros. Co., 1st and Baxter, Superior, Wis. (Gwin A. Whitney.)

Whitney, Chas. S., 306 Colby & Abbott Bldg., Milwaukee, Wis. (Hoel & Johnson.)

Wickersham, John H., 53 N. Duke St., Lancaster, Pa.

Widmer, Arthur J., 941 Century Bldg., St. Louis, Mo.

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Wilson, Jos. P., 8026 Moffatt St., Detroit, Mich.

Wilson & Co., R. F., 1851 Elston Ave., Chicago Ill. (R. F. Wilson.)

Wilson's (N. Z.) Portland Cement, Ltd., Box 269 G. P. O., Auckland, N. Z.

Winell, V. E., 51 Wall St., New York, N. Y. (Thompson-Starrett Co.)

Wisconsin University Library, Madison, Wis. (W. M. Smith.)

Wiseman, W. J., 1942 Forbes St., Pittsburgh, Pa. (Booth & Finn, Ltd.)

Withey, Morton O., 1921 W. Lawn Ave., Madison, Wis. (University of Wisconsin.)

Wolf, Henry W., 1628 Gladstone Ave., Detroit, Mich.

Wolpert, Otto, 51 Wall St., New York City. (Thompson-Starrett Co.)

Wolverine Portland Cement Co., Coldwater, Mich.

Wood, Travers, Mutual Bldg., Richmond, Va. (Ferro Concrete Construction Co.)

Woodle, Jr., A. S., c/o The Baldwin Locomotive Works, Philadelphia, Pa.

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Worcester, J. R., 79 Milk St., Boston, Mass.

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Wright & Kowalski, 15 Exchange Pl., Jersey City, N. J. (Donald A. Wright.)

Wu, Pond S., Supervisor of Works, Govt. Salt Administration, Peking, China.

WYNN, J. W., c/o Engstom & Knapp, 419 Wheeling Steel Corp. Bldg., Wheeling, W. Va.

YAMAMOTO, TAMESABURA, Yarikicho, Osaka, Japan.

YANDELL & CONGER, E. Lafayette St., Jackson, Tenn. (C. H. Yandell.)

YEOMAN, R. C., 603-4 Occidental Bldg., S. E. Cor. Washington and Illinois Sts., Indianapolis, Ind. (Indiana National Sand & Gravel Producers Assn.)

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YOUNG, Q. L., American Trading Co., 4 Consular Road, Tientsin, China.

YOUNG, R. B., 8 Stracham Ave., Toronto, Ont. (Hydro Electric Power Comm.)

YOUNG, R. N., Bureau of Standards, Washington, D. C.

YOUNG, R. W., Paullina, Iowa.

YOUNG, THOMAS F., 8 Great George St., Westminster, London, S. W. 1., England.

YOUNGSTOWN BURIAL VAULT CO., 546 E. Indianola Ave., Youngstown, Ohio. (E. E. Kling.)

ZANESVILLE CEMENT PRODUCTS CO., Box 403, Zanesville, Ohio. (W. S. Jacobs.)

ZEIDLER, JOHN L., 401 Francis St., St. Joseph, Mo. (Zeidler Concrete Pipe Co.)

ZIEGLER, A. WARREN, Ferro Concrete Construction Co., Cincinnati, Ohio.

ZIPPRODT, ROY R., 410 Grain Exchange Bldg., Sioux City, Iowa.

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